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# DEVELOPING AN INQUIRY AND HANDS-ON TEACHING MODEL TO GUIDE STEAM LESSON PLANNING FOR KINDERGARTEN CHILDREN

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**Abstract.** *When contextualizing educational methods, teachers can focus on constructivism to develop inquiry materials as STEAM subject matter for use in schools. However, there is little research concerning what STEAM teaching resources teachers view as inquiry with hands-on STEAM instructional material for use in kindergartens. Therefore, this research used a spiral developmental course design with action research to apply a teaching inquiry and hands-on STEAM model focusing on lesson development for kindergarten children via a one-year workshop. The lesson development process of this research included a total of six stages, allowing 24 participating teachers to analyse the STEAM elements from their original lesson plans, then make revisions according to a model, including: prediction, do/observation, quiz/discussion, and explanation/ transfer (PD/OQ/DE/T). After the initial lesson plan was completed, teaching experiments were conducted, and the lesson plan was adjusted through reflection and revisions based on the suggestions of domain experts during the implementation process. Finally, 48 PDOQDET inquiry and hands-on based STEAM lesson plans were developed. Thus, it is proposed that the inquiry and hands-on i-STEAM modules developed using the PDOQDET approach can represent exemplars illustrative of an enriched design constructivist paradigm to support students' i-STEAM learning in kindergartens.*

**Keywords:** *early childhood education, hands-on learning, inquiry teaching, lesson plan design, STEAM*

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## Introduction

STEM (science-technology-engineering-mathematics) plays a vital role in educating people to cope with major challenges in the future. STEAM education for children aims to help children express STEM concepts by integrating and applying art in STEM courses (Hobbs, 2019; Piro, 2010). Nevertheless, this integrated STEAM learning scheme has not been fully linked with inquiry and hands-on learning in the current education research. Most of the existing STEAM courses are taught with teaching media such as robots (Choi et al., 2018), building blocks (Hansel, 2015) and programming education (Kim & Choi, 2018), but this is still inadequate to underline the combination and application of interdisciplinary knowledge as emphasized in STEAM education. In addition to the emphasis on software application, most STEM is implemented with single domain knowledge (Kim & Choi, 2018). Considering this, Kuo et al. (2019) discussed the importance of interdisciplinary STEM, and suggested implementing it through project-based learning at college level. Over the past decade, STEM has been highlighted in the education for secondary school students, but little attention has been paid to the importance of STEAM education for children (DeJarnette, 2018). Zhou et al. (2019) found that applying a project-based integrated STEM program can have a positive effect on students' attitudes towards STEM covering the primary level; but few studies related to interdisciplinary STEAM (i-STEAM) learning have been extended to kindergartens. Thus, the present research aimed to develop an i-STEAM teaching plan to contribute to STEAM education for kindergarten children.

According to the cognitive-developmental theory proposed by Piaget (1985), pre-school children engage in thinking, but their thinking tends to be autistic, and they have to follow a regular procedure to express scientific ideas (Hong et al., 2014). That is, if children are able to acquire direct experience through practice, they will have a deeper understanding of the knowledge of science (National Research Council, 2012). Inquiry learning can be



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designed with hands-on science activities to enhance learners' interest and curiosity (Bulunuz, 2012; Eshach et al., 2011; Sotakova et al., 2020). Nonetheless, in Taiwan, many curricular activities in early childhood education still focus on children's acquisition of knowledge and neglect the necessary inquiry process (Liu, 2017). Pedaste et al. (2015) reviewed articles related to inquiry phases and summarized five distinct general inquiry phases: "Orientation, Conceptualization, Investigation, Conclusion, and Discussion. Some of these phases are divided into sub-phases. In particular, the Conceptualization phase is divided into two (alternative) sub-phases, Questioning and Hypothesis Generation; the Investigation phase is divided into three sub-phases, Exploration or Experimentation leading to Data Interpretation; and the Discussion phase is divided into two sub-phases, Reflection and Communication" (p. 47). However, the existing STEAM inquiry and hands-on courses vary in quality, and some of them even lack a complete description of what is included in STEAM education (Jamil et al., 2018). Against such a backdrop, it is essential to promote children's inquiry-based hands-on learning. Despite the growing consensus that different lesson plans offer different opportunities for children to learn STEAM, few lesson plans have incorporated STEAM with hands-on inquiry for kindergarten children to experience. As Runnel et al. (2013) pointed out, a model for guided inquiry-based learning is essential to conduct students' science learning, but no framework with an emphasis on hands-on phases in STEAM education was found in the literature. This research therefore developed the inquiry-based with hands-on learning model - PD/OQ/DET (prediction, do/observation, quiz/discussion, explanation and/or transfer) for kindergarten teachers to design i-STEAM teaching materials.

Herro and Quigley (2016) argued that STEAM is an educational concept which enables students to learn through interdisciplinary subjects and apply integrated knowledge to solve problems in reality. Thus, this research showed the potential of using students' "everyday life" as a STEAM resource for supporting them in hands-on learning. Moreover, developing teaching plans is an indispensable part of the advancement of children's inquiry and hands-on learning. The spiral circulation model in the three-step change theory by Lewin (1947) is taken as an essential model to develop teaching plans (Casey & Dyson, 2009). The three steps are planning, action and assessment, and then a new circulation process will start after the assessment of the previous one (Khanlou & Peter, 2005). Therefore, a flexible spiral process allows spontaneous actions (change and improvement) to construct learning processes (Mejía et al., 2007). The model has been widely applied to curriculum development and teaching improvement. By using the spiral curriculum development process, this research developed inquiry-based with hands-on STEAM teaching plans in six stages to process and construct so-called "inquiry-based with hands-on i-STEAM" for kindergarten teachers to follow if they want to develop their own courses.

### *Inquiry-Based Hands-On Learning*

Inquiry-based education is student-centred learning and teaching, in which students learn and inquire via adopting inquiry methods (Maaß & Artigue, 2013). It is also taken as an educational strategy which enables students to acquire knowledge with the methods similar to those used by professional scientists or in a similar way to which scientists practice (Keselman, 2003). For example, science-oriented inquiry-based learning involves supporting students to gain scientific knowledge through scientific experiments rather than from teachers (Cavas, 2012; Jerrim et al., 2019: Teig et al., 2018). Many studies have suggested that hands-on practice can be integrated with inquiry teaching (Zhang, 2019). In the process of inquiry learning, quizzes can test if participants have understood the objectives of a target unit (Hong et al., 2019). The core characteristic of the inquiry module is designing the learning materials that are confusing and urgently expected to be demonstrated. Hong et al. (2019) set forth an inquiry model form, POE (predict—observe—explain), and added a quiz to ensure that participants understand the objective of the unit through the POQE inquiry model consisting of Prediction, Observation, Quiz and Explanation.

Minner et al. (2010) argued that the students who learned through experimentation would have a deeper conceptual understanding; some scholars also mentioned that learning based on the tactile sense would generate motor imagery and stimulate the operation of the prefrontal lobe of the brain, which would enhance learning concentration (Stout et al., 2015) and result in better learning effects (Cantillo-Negrete et al., 2019). In addition, hands-on learning would activate the cerebral cortex, promote the modulation of acquired information, and strengthen the brain's capacity of processing information, thus increasing learning efficiency (Maes et al., 2017); besides, practice would reinforce students' learning motivation (Jerrim et al., 2019). In hands-on learning, children should be assisted to gain a deeper understanding of nature and acquire science concepts and relevant knowledge (Hong & Diamond, 2012). Meanwhile, the science activities in the classrooms of early childhood education usually arouse children's interest and trigger their participation (Greenfield et al., 2009).


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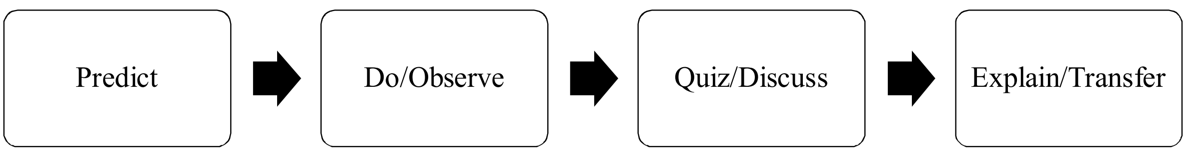
Hardy et al. (2005) mentioned that curricular activities that promote conceptual difference, including quality, volume and density, could have both immediate teaching effects and far-reaching effects involving explanatory information. It is important that children learn in such a way that they can transfer their knowledge to different problems, settings, and time (Klahr & Chen, 2011). Marcus et al. (2018) explored the types of conditions that support young children's learning and transfer across hands-on STEM problem-solving activities. Moreover, a previous study revealed that science teaching has been focusing on withholding answers from teachers until inquiry activities are completed so as to develop learners' high-level science learning (Zhang, 2019). Considering that withholding answers is a way to trigger and maintain students' engagement in science learning, this research moved science explanation to the last phase of the inquiry cycle. In addition, most STEAM programs incorporate project-based approaches, the design-process, or hands-on experiences, but they often overlook the key aspects including conveying meaning and transferring knowledge (Huber et al., 2016; Perignat & Katz-Buonincontro, 2019). Taken together, by extending from POQE, this research added such inquiry steps as "do" and "transfer" to extend the PDOQDET (predict-do/observe-quiz/discuss-explain/transfer) from the POQE inquiry learning model. Thus, this research extended the POQE inquiry learning model into the P—D/O—Q/D—E/T (hereafter, PDOQDET) inquiry and practice teaching model which includes predict (P), do (D), observe (O), quiz (Q), discuss (D), explain (E) or transfer (T) (i.e., if some concept is hard to explain to children, then use similar examples to evoke their thinking), as is shown in Figure 1.

**Figure 1**
*PD/OQ/DE/T Inquiry Module*




*Research Questions*

The principle of STEM education is to acquire the expertise of science, technology, engineering and mathematics, and to utilize the knowledge to detect problems and support STEM-related learning, including inquiry, design and analysis (Bybee, 2010). The most important part of STEM education is integration, which indicates integrating the STEM subjects with the purpose of solving problems in the real world (Labov et al., 2010; Sanders, 2009). To offer STEAM education, it is necessary to be clear about how to connect and combine the five domains and create the elements for undertaking innovative STEAM education (Park, 2013). Therefore, its interdisciplinary nature and arts are the fundamental constituents of STEAM education (Thuneberg et al., 2018). Moreover, from a pedagogical perspective, the complex learning process can be divided into smaller, logically connected units that scaffold students and draw their attention to key features with scientific thinking (Pedaste et al., 2015). These individual units are called the inquiry cycle, and how PDOQDET sets the connections to form an inquiry cycle was explored in this research. Accordingly, the research questions were proposed as follows.

RQ1: How can PDOQDET be applied to develop a hands-on educational model?

RQ2: What i-STEAM components can be extracted when developing hands-on inquiry lesson plans?

**Research Methodology**

*Research Method and Implementation*

General background

Action research is a combination of research and action, where researchers and doers collaborate to advance practical and theoretical building (Nielsen, 2016; Nolen & Putten, 2007). Hence, this research adopted action research to develop STEAM inquiry and hands-on teaching plans. Accordingly, the target teachers were invited to review the previous developmental teaching plans after their design, and took part in experiments at their kindergartens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with the teaching plans; thus, several rounds of this action research were performed to achieve better i-STEAM inquiry with hands-on teaching plans.

Over the past 2 decades, action research in education has attracted increasing attention. Regarded as a pragmatic and traditional research method, it enables teachers to investigate their teaching and the learning of their students (Nolen & Putten, 2007). Hence, action research is a research strategy that combines knowledge generation and practical changes (Trollvik et al., 2013) and is thus taken as a critical tool to promote introspective practice and educational reform. Aside from enriching the meaning of teachers' course designs, it provides diverse ways for students to experience education, and serves as a thorough test of their practice (Price, 2001).

### Participants

Considering the spiral process, there were nine professional development workshops conducted for the kindergarten teachers. There were 30 teachers who had at least 5 years' teaching experience in kindergartens and who expressed interest in joining this workshop, of whom 24 were selected and recommended by the Taipei City Educational Bureau to attend the workshops.

### Procedure

According to the concepts of course development by Laudonia et al. (2018) and the modules based on the spiral circulation model (Lewin, 1947), such steps as planning, action and evaluation were extended to form a draft proposal (planning), draft revision (action), teaching implementation (action), and assessment and teaching plan revision (evaluation). At the beginning of the workshop each attendee expressed ideas about teaching plans and came up with five feasible teaching plans. That is, in the beginning of the spiral process, each participant presented five themes for content development by proposing a draft and presented it to three domain experts, all of whom are professors who have published STEAM-related articles. In the second to fifth run, the participants implemented trial teaching and follow-up revision, and presented their results to the three experts. In the final spiral process, nine workshops were held, and themes of two of the workshops were selected. Then, these two teaching plans were tested at the teachers' own kindergartens to understand what teaching plans can fit the model of P—D/O—Q/D—E/T (hereafter, PDOQDET) with i-STEAM inquiry and hands-on learning for kindergarten teachers to use. Consequently, the workshop started in February 2019 and ended in December 2019.

Moreover, the STEAM teaching plans and the inquiry with hands-on learning process were divided into two parts, proposal and revision for the development and modification of spiral teaching plans. The development of the teaching plans in this research was divided into the following six phases.

*The Workshop of PDOQDET Lesson Plan Development*

#### Phase 1: Propose the Draft of the STEAM Teaching Plan

When adopting a sociocultural approach to instruction, teachers should support "children in their development by guiding their participation in relevant activities, helping them to adapt their understanding to new situations" (Rogoff, 1990, p. 191). In other words, they should find appropriate resources to design lesson plans which can support the students in their productive interactions (Mercer & Howe, 2012; Newman et al., 1989). Resources taken from everyday practices can be considered as mediational means for supporting students' learning about issues and themes (Silseth & Erstad, 2018). Moreover, Kim et al. (2012) proposed three elements, namely the unit (concept/skill, question/phenomenon, and activity), degree (multidisciplinary or interdisciplinary) and environment (individual, society and the world), for the integration of STEM. As increasing attention is paid to STEM education in schools, different possibilities can be offered for students to experience, so that they will build a foundation for STEM learning from their daily life (Watson et al., 2020). As has been mentioned above, an interdisciplinary combination of daily life and hands-on experience should be highlighted in the development of STEM or STEAM courses to deepen learners' understanding of science concepts and knowledge; thus, before the first workshop, the targeted teachers were asked to review their existing teaching plans and select some themes close to the kindergarten children's life experience, and present them at the first workshop.


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Phase 2: Revise the Draft of STEAM Teaching Plan

According to the definition of STEAM in the prior section, the STEAM elements selected by the participant teachers, and the discussion among the three STEAM scholars, this phase was to achieve more complete analytical results through expansion and revision. For example, "CUP DO REI MI" as follows:

**Table 1**
*The STEAM Component Analysis of the Teaching Plan "CUP DO REI MI"*

| Domain | Definition | Analysis |
|---|---|---|
| Science | Application of the properties of materials as well as the interaction between and changes to substances | Materials (glass, steel and paper) and struck parts (mouth and body) of cup and the volume of water in the cup are all related to the sound. |
| Technology | Application of devices, tools and processing methods | Use tools like spoons to strike a specific part of the cup to get a pleasant sound. |
| Engineering | Various "operations and functions" of engineering, with emphasis on the maximum utilization of resources and functions | Achieve the best arrangement of such variables as the material and struck part of the cup and the degree of force to find out the ways to get the best melody. |
| Art | The practice of creativity and the expression of aesthetic ideas | The combination of visual and audio effects of the arrangement of cups. |
| Mathematics | Counting, applying algorithms, and obtaining percentages | Gradually increase the water in the cup to see that the water level rises with increasing water, and count the volume of water in each cup. |

Phase 3: Propose the Draft of the PDOQDET Teaching Plan

The hands-on learning with difference comparison would bring children strong sensory experience. For that reason, the emphasis of the inquiry and hands-on activities in this research was placed on different sensory experiences. For example, the idea draft of CUP DO REI MI:

1) Inquiry into different materials: Cups made of three different materials were struck, and the children were asked to listen to the sound to see if there were any differences in the sound produced.
2) Inquiry into the same materials with different water levels: Different volumes of water were poured into the glass cups, and the cups were struck to see if there was any difference in sound. The children were asked to practice throughout the process for a deeper impression.
3) Explanation (1): a simple method was used to explain the reasons for the different sounds from the cups made of different materials and with different volumes of water. Explanation (2): After the course, five glass cups with different volumes of water were placed in the learning zone, so that the children would be able to strike the cups for the musical notes like "do," "re," "mi," "fa" and "so" all by themselves.

Phase 4: Modifying the Draft of Teaching Plans

Most teachers were not used to writing out lesson plans by following the proposed inquiry with hands-on learning model, or mixing several plans in a lesson. In this phase, they had to work on trimming and focusing on one single plan. In the CUP Do Rei Mi course, for example, the mission for children was to predict different materials to strike and create sound. That is, the teachers asked the children to predict if the paper, metal and glass cups would create the same sound. If they predicted that the sound would not be the same, the teachers asked them to explain the possible reasons for the difference. They also asked the children to predict if the cups with different volumes of water would create the same sound. If they predicted that the sound would not be the same, they asked them to explain the possible reasons for the difference. In line with this, the participants must focus on a single concept, such as using glass cups only for conducting PD/OQ/DE/T. For example, a completed proposal before trimming is presented below.


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*Predict*

1) Ask the children to predict if the cups made of different materials and the cups with different volumes of water would create the same sound when struck.
2) Ask the children to predict if the paper, metal and glass cups would create the same sound. If they predicted that the sound would not be the same, ask them to explain the possible reasons for the difference. Ask the children to predict if the cups with different volumes of water would create the same sound. If they predicted that the sound would not be the same, ask them to explain the possible reasons for the difference.

*Do/Observe*

1) Ask the children to strike the paper, metal and glass cups all by themselves to feel the sound created in the striking.
2) Lead the children to discuss the methods of changing sound. For instance, strike the paper and glass cups to see which one creates a clearer sound; strike the glass cup with the smallest volume of water and the one with the largest volume of water to see which one creates a sharper or weaker sound.

*Quiz/Discuss*

1) Ask the children the reasons for the phenomenon.
2) Discuss with the children why the sound from the glass cups was the clearest and why the sound from the glass with the smallest volume of water was the sharpest.

*Explanation/Transfer*

1) A paper cup is softer while a glass cup is harder. When a metal spoon hits a hard object, the sound created by the striking will be clear. The volume of water in a glass cup would change the natural frequency of the vibration of the whole cup. A smaller volume of water leads to a higher natural frequency and thus a sharper sound; a larger volume of water results in a lower natural frequency and thus a weaker sound.
2) What shares the same or similar principle in daily life? What objects made of different materials would create different sounds when they are struck? What objects of different sizes would create different sounds when they are struck? What are the other objects in daily life that would create different sounds according to their height or length, just as the "do," "rei" and "mi" from the glass cups?

Note: After trimming, the PD/OQ/DE/T of CUP DO REI MI is described in the section of Exemplary 1.

Phase 5: Demonstrate the Inquiry and Hands-On STEAM Teaching

In this PD/OQ/DE/T way, the teaching plans by the participant teachers were implemented to gather the feedback from the children, and then the feedback was used for the follow-up improvement of the teaching plans. For example, do and discuss in the CUP DO REI MI course.

Phase 6: Undertake Evaluation and Revise Teaching Plan*s*

Many improvements and reforms are realized in the course of development (Groundwater-Smith, 2019). Continuous quality improvement is the key to being successful in project work (Hong et al., 2020). Therefore, teachers need to focus on students' knowledge of a theme, in which they need to challenge the concepts (Park et al., 2011). For that reason, the participants conducted and observed the children's responses to their own course plans, and reported to two lecturers (scholars of early childhood education) to adjust and revise the final version of PD/OQ/DE/T along with STEAM. Thus, they could offer better teaching plans for the targeted learners.


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*Exemplary PDOQDET Inquiry Teaching Pla{n*

With this PDOQDET inquiry process, this research aimed to provide children with better science knowledge. The design format of the teaching plans is shown in Appendix 1, and the information about the examples of the teaching plans is provided as follows:

Example 1: CUP DO REI MI Teaching Plan

*Preparation activity*

1) Align eight paper cups on the desk; pour some water into the first cup so that it is half full; pour twice as much water as is in the first cup into the eighth one (measured with a ruler); pour increasing amounts of water into the second to seventh cups. The same steps are also taken for the metal and glass cups (see Figure 4). Finally, there are three lines of cups containing different volumes of water. The children are invited to do all the above things.
2) Test the sound from the cups made of different materials and strike the cups to find out the parts that create a pleasant and clear sound.
3) Get familiar with the musical scale of the eight notes, including DO, RE, MI, FA, SO, LA, TI, and DO.
4) Teaching tools and materials: eight glass cups (bottles), a metal spoon, and water

**Figure 2**
*The Teaching Tools*

*PDOQDET of the teaching*

*Predict*

Ask the children to predict if the glass cups with different volumes of water would create the same sound.

*Do/Observe*

1) Do: Invite the children to put on a cup-striking performance with the water-filled cups on the platform.
2) Observe: Lead the children to observe the changing sound. For instance, strike the glass cup with the smallest volume of water and the one with the largest volume of water to observe which one creates a sharper or weaker sound.

*Quiz/Discuss*

1) Quiz: Ask the children the reasons for the phenomenon.
2) Discuss: Allow the children to discuss why the sound from the glass with the smallest volume of water is the sharpest.

*Explain/Transfer*

1) Explanation: The volume of water in a glass cup would change the natural frequency of the vibration of the whole cup. A smaller volume of water leads to a higher natural frequency and thus a sharper sound; a larger volume of water results in a lower natural frequency and thus a weaker sound.
2) Transfer: 1) Near transfer: What are the other objects in our daily life that would create different sounds according to their height or length, just as the "do," "rei" and "mi" from the glass cups? For example, bottles or paper cups. 2) Far transfer: What are the other objects in our daily life that would create different melodies according to the songs children are familiar with.


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*STEAM knowledge and concepts*

(1) Science: The part of the glass cup which is struck, and the volume of water in the cup are all related to the sound frequency created.

(2) Technology: 1) Use tools like spoons to strike a specific part of the cup to get a pleasant sound. 2) Find out the sequences of striking cups that would create various melodies.

(3) Engineering: The part of the cup which is struck and the degree of force to find out the most pleasant sound or melody.

(4) Art: The aesthetic experience of vision, touch and listening.

(5) Mathematics: 1) Gradually increase the volume of water and find that a larger volume of water leads to a higher water level. 2) No. of glass cups can create no. of sound frequencies.

Example 2: Teaching Plan of Cleaning-Rag

*Preparation activities*

1) Use cleaning-rags made of three different materials to wipe off water and stains in the experiment to see which cleaning-rag is the most effective.
2) Teaching tools: Prepare three different rags made of different textiles (see Figure 3).

**Figure 3**
*The Teaching Materials and Tools*

*Description of PD/OQ/DE/T teaching*

*Predict*

1) Predict which cleaning-rag will be the most effective for wiping off stains.
2) Ask the children to predict if the three kinds of cleaning-rag are different, which one would be the most effective for wiping off stains.

*Do/Observe*

1) Lead the children to the graffiti wall outside the classroom, and invite them to clean the wall with the cleaning-rags made of the three different materials to see which cleaning-rag works best.
2) Ask the children to use the cleaning-rags containing different amounts of water to clean the graffiti wall to observe which kind of cleaning-rag is the most effective for wiping off the stains on the wall.


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*Quiz/Discuss*

1) Ask the children the reasons for the difference.
2) Lead the children to discuss why the towel cleaning-rag was the most effective for wiping off the stains.

*Explanation/Transfer*

1) Explanation: The cleaning-rag made of the long fibre towel has a large coverage that creates more friction and is thus more effective for wiping off the stains.

2) Transfer: i) Near transfer: How can we use different kinds of cleaning-rags according to different situations in our daily life? For example, handkerchief or towels. ii) Far transfer: From the perspective of engineering, try to find out which pose or method is the most effective for drying the cleaning-rag.

*STEAM knowledge and concepts*

1) Science: Different kinds of cleaning-rags differ in terms of absorbing water with capillary action and wiping off stains with friction.
2) Technology: The process of cleaning desks; try not to repeatedly clean the same places.
3) Engineering: The best proportion of containing water without dripping from different cleaning-rags when using them to clean stains on the wall.
4) Art: Explore the cleaning-rags made of different materials and feel the differences among them and the beauty of the texture.
5) Mathematics: How large is the wall to be cleaned and what frequency of cleaning can be effective.

**Research Results**

Based on the exemplary lesson plan, 48 i-STEAM PODQDET inquiry with hands-on teaching plans were developed. The lesson plans are divided into eight categories: cooking, building blocks, sliding and turning, measuring, paper, colours, animals and plants, and others (see Table 2).

**Table 2**
*Exemplary Lesson Plans*

| No. | Categories | Lesson name |
|---|---|---|
| 01 | 1 Cooking | Dough experiment |
| 02 | | Water adding into flour game |
| 03 | | Flour to noodle transformation |
| 04 | | Farfalle |
| 05 | | How to make a tasty panna cotta? |
| 06 | | How to make a pretty and surprising panna cotta? |
| 07 | | The Sticky Tangyuan - Inquiry I |
| 08 | | The Sticky Tangyuan - Inquiry II |
| 09 | | Yummy Sushi 1 - Time to cook! |
| 10 | | Yummy Sushi 2 - Sushi |
| 11 | | Washing AiYu jelly |
| 12 | 2 Building blocks | Domino diving |
| 13 | | Exciting toy brick robot |
| 14 | | The moving robot |


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| No. | Categories | Lesson name |
|---|---|---|
| 15 | 3 Sliding and turning | The funny luge |
| 16 | | Play marble |
| 17 | | Pinball machine |
| 18 | | The spinning windmill |
| 19 | | The interesting paper gyro |
| 20 | | Elasticity Plane |
| 21 | 4 Measuring | Jogging step counting |
| 22 | | The length of throwing a ball |
| 23 | | How far does the paper plane fly? |
| 24 | | The competition of stacking high |
| 25 | | Aluminium foil boat |
| 26 | | The floating clay |
| 27 | | Ring toss |
| 28 | 5 Paper | What kind of paper do we use in the bathroom? |
| 29 | | My plane can turn |
| 30 | | Paper dragonfly |
| 31 | | Paper popper |
| 32 | | The tasty paper |
| 33 | | Paper flowers float on the water |
| 34 | | The comparison of paper |
| 35 | 6 Colours | The magic sand |
| 36 | | Watercolour is fun 1 |
| 37 | | Watercolour is fun 2 |
| 38 | | The rendering paper |
| 39 | | The blowing paint |
| 40 | | Star sand |
| 41 | 7 Animals and plants | Babysitter of Pale White Butterfly |
| 42 | | Planting butterfly pea |
| 43 | | Drying butterfly pea 2 |
| 44 | 8 Others | The comparison of bubble blowing tools |
| 45 | | Bouncing bubble |
| 46 | | Cup DO REI MI |
| 47 | | Where does the light go? |
| 48 | | Cleaning-Rag |

## Discussion

RQ1: How can PDOQDET be applied to develop a hands-on educational model?

A previous study revealed that science teaching has been focusing on withholding answers from teachers until inquiry activities are completed so as to develop learners' high-level science learning (Zhang, 2019). For example, Pedaste et al. (2015) summarized inquiry phases including Phase 1: Orientation; Phase 2: Conceptualization of the phenomenon; Phase 3: Investigation of the phenomenon; Phase 4: Conclusion of the investigation; and Phase 5: Discussion. This pedagogical model or framework for the process of inquiry learning includes the student moving


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through answering questions to supporting their observation to explaining the learning concepts or to connecting similar phenomena (Kuhlthau et al., 2015). However, teaching must be done in a way which serves children's natural curiosity and their need for hands-on activities (Kuhlthau et al., 2015). For example, Casey et al. (2019) explored whether 3- and 4-year olds could be actively engaged in social studies practice through inquiry learning in a school garden, and the results imply that working in a school garden through inquiry learning can foster the development of curiosity and social competencies. Moreover, in a study by Mamun et al. (2020), the inquiry design referred to as predict, observe, explain and evaluate (POEE) can enhance students' interactions and engagement and enable self-directed inquiry. Huber and colleagues (2016) found that preschool-aged children were able to learn how to complete a problem-solving task and transfer learning to a physical context. Considering this, this research presented an explanation of reasons or knowledge transfer at the last stage of PDOQDET, which seems to meet the growing needs for i-STEAM hands-on inquiry education.

RQ2: What i-STEAM components can be extracted in developing hands-on inquiry lesson plans?

It is necessary to integrate all relevant subjects to advance STEM education, so STEM education lays emphasis on knowledge and interdisciplinary content. The highlight of the integration method of STEM education is that at least two STEAM subjects are used to construct application steps, especially those of practical significance (Liao, 2016). Regarding the "science" component which is extracted from i-STEAM inquiry with hands-on learning lesson plan development, this research confirmed that science is about "applying the properties of materials as well as the interaction between and changes to substances."

Regarding the "technology" component which is extracted from i-STEAM inquiry with hands-on learning lesson plan development, this research confirmed that technology is about the "application of devices, tools (e.g., computers) and processing methods" rather than both hands. This is supported by Longman (2020), who defined technology as the machinery and use equipment to process or assemble materials which are embedded with the application of scientific knowledge.

Regarding the "engineering" component which is extracted from i-STEAM inquiry with hands-on learning lesson plan development, this research confirmed that engineering is about "operations and constructions" of devices, with emphasis on the maximum utilization of resources and function speeds, the minimization of technical problems, the exquisiteness, stability and durability of machinery, and the operational smoothness of objects. As children show an innate tendency of engineering thinking, teachers can support engineering-driven STEM education (English, 2018).

Regarding the "arts" component which is extracted from i-STEAM inquiry with hands-on learning lesson plan development, this research confirmed that arts is about "the experience and appreciation of humanistic aesthetics, the practice of creativity, and the expression of aesthetic sense." Supported by Costantino's (2018) transdisciplinary curriculum model, arts include art production or making, performing, interpreting meaning, self-expression, critiquing, and exhibiting or presenting works of art.

Regarding the "math" component which is extracted from i-STEAM inquiry with hands-on learning lesson plan development, this research confirmed mathematics as "counting, applying algorithms, obtaining percentages and symmetry, computing the exercise force of objects, and achieving the co-making nature of space and object." Supporting English's (2018) assertion, mathematics can be constructed through the activities of technology and engineering.

**Conclusions and Implications**

Inquiry learning has been proved useful in expanding knowledge. However, the number of studies on the inquiry learning of early childhood education remain small. With the PDOQDET inquiry learning, this research utilized a simple but inquiry teaching process to help learners acquire STEAM knowledge through hands-on practice. Although a qualitative or quantitative teaching demonstration was not carried out, the PDOQDET inquiry learning was of great interest to the participating teachers. They reported that they could construct their teaching plans through the draft-test-revise cycle, enabling them to develop teaching plans themselves and giving them more confidence in teaching kindergarten children to become involved in hands-on inquiry-based i-STEAM learning.

It has been shown that inquiry learning is a stepwise process, whereby children continuously enrich and reconstruct their knowledge in the concept explanation framework based on daily experience. Hence, this research


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does not suggest adopting standardized materials (such as the teaching material sets in the market) as the STEAM inquiry and hands-on teaching plans; instead, it suggests collecting teaching materials from the objects or phenomena that are frequently seen by children in their daily life, and developing these materials into i-STEAM PO/DQ/DE/T inquiry with hands-on teaching model. It is expected that this model may be more effective in terms of advancing science education for children.

The inquiry educational model, starting with predicting something rather than explaining it directly to children will be able to help them deepen their understanding of knowledge. Specifically, an appropriate inquiry model design, such as focusing on i-STEAM PODQDET, should be adopted for those children whose cognitive capability is still in the early stage; it is not recommended to give obscure reasons (e.g., scientific reasons) or explanations for science phenomena to children as it can prevent them from losing their curiosity and interest in STEAM; however, in most cases, we suggest that teachers can use the "transfer" phase to encourage students to think about similarities and the application of what they have learned.

### *Future Studies*

Inquiry learning is deemed as a highly valuable educational method which helps learners gain a comprehensive and specific understanding of knowledge, and improves their cognitive skills. This research emphasizes the design and development of the i-STEAM inquiry and hands-on teaching plans, but the effects of the teaching plans were only shown in the trial teaching, and a large-scale teaching practice has not yet been implemented. Therefore, it is suggested that future studies can explore the effects of the STEAM inquiry and hands-on teaching plans from multiple perspectives, such as the children's cognition, emotion and attitudes.

Inquiry refers to the methods and procedures adopted by scientists, and is a way of understanding new information, but individual disposition can influence the effectiveness in different countries. Following their cross-country study, how individual traits can influence the PDOQDET in different countries may be the subject of future studies.

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