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Research Article:

Science Teachers' Uptake of Heuristic Educative Curriculum Materials to Develop Students' Habit of Questioning and Posing Problem

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ABSTRACT

Science teachers lack the pedagogical knowledge and skills to develop students' habit of questioning and posing problems (HQP), which is vital for scientific inquiry. Prescriptive curriculum materials do not promote professional growth and development in teachers. In contrast, heuristic educative curriculum materials allow teachers to choose and learn as and when is more feasible. Heuristic design curriculum materials contain educative features that provide suggestions and rationales for instructional activities, empowering teachers to enact more flexibly. In a larger study, a heuristic curriculum material called Skilful Thinking Educative Pedagogical Support (STEPS) was prepared and encompassed three components – specific thinking strategies, habits of mind, and metacognition. STEPS was prepared using findings from needs analysis, a review of additional curriculum materials and the Malaysian Year 4 science syllabus. This paper focuses HQP which is one of the sixteen components of habits of mind. The research objective was to investigate how three Year 4 science teachers up-took educative features in STEPS to develop students' HQP. The study utilised a qualitative exploratory research design. Classroom observations, open-ended interviews, and document analysis were the data sources. We used tracers in the educative features, such as teachers' uttered phrases, cues, and suggested tools to indicate HQP implementation. The findings showed fidelity between STEPS and teacher implementation as teachers had used the suggested tools, encouraged students' HQP skills by using cues, and gave justifications on why HQP is important. The teachers also gave space and scaffolded their students' question generation and problem-posing. Moreover, teachers adapted the educative features most relevant to their teaching context. Implications for teachers, school leaders, researchers and teacher educators were discussed.

Keywords: Educative curriculum materials, habits of mind, heuristic design, posing problems, questioning, science teachers

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INTRODUCTION

Inquiry-based learning is one of the best approaches to teaching science (Cairns & Areepattamannil, 2019). However, to have an impact on student learning, two things must be in place. Firstly, teachers must possess relevant pedagogical knowledge and skills to ask questions or inquire as cues to stimulate students' thinking (Amels et al., 2019; Costa & Kallick, 2015). Secondly, teachers must encourage students to ask questions (Jacobs & Renandya, 2021; Kawalkar & Vijapurkar, 2013). Asking questions often lead to students engaging in scientific phenomena and seeking explanations for what they observe.

Nevertheless, various challenges exist when teachers implement the habit of questioning and posing problems (HQP) among their students (Nair & Ngang, 2012; Qablan & DeBaz, 2015). Teachers tend to be the questioners; thus, finding it difficult to promote students' question generation (Aflalo, 2021). Teachers' belief in students' ability to think (usually the lack of it) often askew teachers' pedagogical decisions on how they engage their students in inquiry-based learning (Qablan & DeBaz, 2015). Furthermore, many teachers are unaware that students require scaffolding from structured inquiry to open inquiry-based instructions. Stemming from this unawareness, teachers do not provide sufficient transition space for students to question and design approaches in seeking explanations (Zion & Mendelovici, 2012).

These challenges demand solutions because developing children's HQP in science classrooms is crucial for sustainable inquiry learning experiences (Biggers, 2018; Salmon & Barrera, 2021). Science teachers often depend on curriculum materials to upskill their knowledge and skills (Zangori et al., 2013). However, these materials come with flaws. Curriculum developers often neglect teachers' ideas, beliefs and understandings when designing curriculum materials for the classroom (Handler, 2010). These curriculum materials are generally structured and rigid (prescriptive), hoping that little training is required for teachers to engage with them (Choppin et al., 2022; Davis & Smithey, 2009). Therefore, teachers enact these curriculum materials "as-is" (Roehrig et al., 2007). Teachers often desert these curriculum materials when they find them too rigid and do not fit their repertoire of knowledge and skills (Biesta, 2005).

Teachers are unaware that adapting curriculum materials is part of their job (Davis & Smithey, 2009). This awareness can be harnessed through heuristic design educative curriculum materials that allow teachers to learn independently, not telling but providing rationales, suggestions, and recommendations. Educative curriculum materials support teacher in learning new instructional practices and scaffold their thinking so that they can independently make decisions during science lessons (Arias et al., 2016; Davis et al., 2017). Hence, teachers become the creators of their lesson plans and classroom enactment through experience, thinking and metacognition (Davis et al., 2017).

This paper is part of a larger study where a heuristic design educative curriculum material called the Skilful Thinking Educative Pedagogical Support (STEPS) was prepared to guide Year 4 science teachers to inculcate skilful thinking. Skilful thinking encompasses three elements: thinking skills, habits of mind and metacognition. This paper focuses on the HQP, one of the 16 Habits of Mind. HQP articulates that teaching science is not only about the acquisition of thinking skills; but also includes the art of asking questions and posing problems, sharing thoughts with peers, and collaboratively analysing science concepts that demand a sustained interest in thinking. This paper aims to trace the teachers' uptake of the recommendations by STEPS as they develop students' HQP.

LITERATURE REVIEW

Even though teachers' questions play a crucial role in "orchestrating and improvising" the classroom discourse (Jurow & Creighton, 2005; p. 277), little is known about how teachers develop the HQP among students (Dohrn & Dohn, 2018; Shanmugavelu et al., 2020). HQP is one of the sixteen thinking skills of a universal framework called the Habits of Mind (Costa & Kallick, 2009). Habits of Mind mean having dispositions like thinking flexibly, striving for accuracy, and applying past knowledge to new situations when confronted with problems where answers are not immediately apparent (Costa & Kallick, 2000). When teachers engage students with habits of mind skills, teachers point out contextual cues in a situation and help students to understand when it is the appropriate time and circumstance to employ the behaviour. Thus, introducing habits of mind helps students to reflect on, evaluate, modify, and carry forth the applications to future learnings.

HQP encourages students to think more deeply about the concept by having a questioning attitude. Developing the HQP enhance students' thinking abilities (Burgess, 2012; Duckor & Perlstein, 2014; Murray, 2016). When students learn to ask questions and pose problems, they gradually acquire the skill to formulate questions for scientific investigations. This stimulates science talk among students and motivates them to seek possible solutions (Kracl & Harshbarger, 2017). Furthermore, as students ask questions or pose problems, teachers can assess students' level of thinking (Aflalo, 2021).

However, teachers must support student question generation and help students find solutions to their problems (Keiler, 2018). Teachers can support students' HQP through heuristic design curriculum materials that educate teachers to adapt the materials for uses and forms according to their instructional context. Stating clear rationales behind the proposed ideas and recommendations are characteristics of heuristic design curriculum materials (Beyer & Davis, 2009; Davis et al., 2014). Based on these rationales, teachers decide how to adapt the materials to their needs (Davis & Krajcik, 2005). The rationales provide a framework for teachers about the ideas underlying the concepts, provide room to integrate their knowledge base and make connections between theory and practice (Davis et al., 2014; Krajcik & Delen, 2017). These materials 'speak to' (Remillard, 2000, p. 347) teachers so they understand the importance of their actions and do not follow blindly (Krajcik & Delen, 2017).

Heuristic design curriculum materials contain educative features, usually vignettes, to inform teachers on how they might employ the new pedagogical strategies and approaches (Arias et al., 2016; Noh & Webb, 2015; Beyer & Davis, 2009; Schneider & Krajcik, 2002).

An example of an educative feature is a fictional teacher designed to explain how a teacher develops HQP among students using the various thinking tools available (Davis et al., 2014). These thinking tools are auditory cues (Dresner et al., 2014; Tzuriel et al., 2017), thinking maps (Hyerle, 2009), and concept cartoons (Keogh & Naylor, 1999; Yilmaz, 2020; Yin & Fitzgerald, 2017). Auditory cues are teachers' questions as prompts; for example, "what can you infer from this?" These cues help students think, and students can use teachers' cues to model subsequent questions about the concept they are learning. Similarly, thinking maps help students link concepts they have learned and generate further questions about the interlinking concepts.

To stay relevant, these educative materials must highlight teachers' potential difficulties and provide suggestions for overcoming them. It is challenging for teachers to inculcate HQP among students, especially in the Asia Pacific region, where students are passive and dependent on teachers for directions and knowledge input (Fatima & Ahmad, 2013; Tuyet, 2013). The educative curriculum materials must suggest how to encourage students to talk before cultivating HQP. Therefore, curriculum materials show teachers how to initiate student talk through group discussions, group their students, and can manage the talk (Metcalfe & Finn, 2013).

The heuristic curriculum materials can be seen as the mediated tool (Bernhard, 2007; Vygotsky, 1978) that helps an individual to learn and interpret new knowledge in "situated social practices" (Svendsen, 2015). There are two levels of knowledge internalisation. Firstly, when teachers interact with the curriculum materials. This participatory relationship (Remillard, 2005) between the teacher and curriculum material is influenced by the teacher's knowledge and skills and the curriculum materials' features and language (Enfield et al., 2008). Secondly, learning occurs through the interactions between the individual and social. For example, the teacher, through interactions with students and the classroom context, learns how to modify the curriculum materials to suit their students' needs. Thus, if these heuristic curriculum materials, more precisely the educative features, are situated within an individual's Zone of Proximal Development (ZPD) (Vygotsky, 1978), the tool can better scaffold teacher learning.

Skilful Thinking Educative Pedagogical Support (STEPS)

The heuristic design was fundamental in preparing STEPS. In developing STEPS, we adhered to design principles for developing educative curriculum materials (Davis & Krajcik, 2005). Firstly, there was a range of productive adaptions aligned with the principles of skilful thinking. Secondly, educative features were grounded in teachers' practices. Here, suggestive tools were recommended for teachers to use in various situations. Thirdly, we understood that teachers' uptake of the content would be distinctive and based on the perceived needs of themselves and their students. Thus, multiple features were provided. Fourthly, teachers' pedagogical content knowledge would evolve as interactions with STEPS occurred. As such, big ideas (or conceptual understanding) on skilful thinking were illustrated to help teachers to select high-value content. Finally, we believed that teachers naturally would take up core ideas about skilful thinking. Thus, features that supported these practices were demonstrated and how teachers can encourage students to achieve higher performance levels.

To ensure STEPS was flexible, user-friendly, and not "teacher-proof" (Barab & Luehmann, 2003), teachers were consulted during STEPS preparation. We conducted a needs analysis, reviewed additional curriculum materials and analysed the primary Malaysian Science curriculum. During the needs analysis, we found teachers' practices to be teacher-centred, and they were the main questioners. When it came to posing problems and designing prototypes to solve problems, the teachers did not support the process. Most of the time, the students were asked to design and build prototypes of devices/objects on their own and present them. As a result, students could not complete them successfully, and usually, there was not much time for discussion. When reviewing the curriculum materials, we found that despite many existing materials, these materials were more prescriptive and lacked educative features. We focused on the Year 4 science topic "Properties of Materials" because the learning outcomes were mostly associated with developing thinking skills.

The findings found that teachers required support in terms of (i) knowledge of skilful thinking, (ii) skilful thinking implementation, and (iii) classroom management and group discussions. STEPS contained nine educative features to support teachers for the three design heuristics (knowledge of skilful thinking, skilful thinking implementation, and classroom management and group discussions). For the knowledge of skilful thinking, four educative features were recommended: teacher-thinking questions (EF1), teacher-reflective writing (EF2), graphical representations (EF3) and teacher tips (EF4). In terms of Skilful thinking implementation, four educative features were put forward – teaching goals (EF5), content boxes (EF6), lesson planning cues (EF7) and fictional teachers (EF8). One educational feature, roadblocks (EF9), was introduced for classroom management and group discussions.

Roadblocks (EF9) responded to teachers being unable to manage small group discussions and not using relevant tools to encourage skilful thinking. Similarly, lesson plan cues (EF7) were designed to provide essential information in planning lessons. Instead of what to do, cues were given to stimulate teachers' thinking while planning their lessons. Cues such as "What are the opportunities given to your students to think about the concept and thinking strategy that they had practised". In addition, STEPS also provided the rationale for why these cues are important. For example, when teachers introduce a specific thinking strategy, it is important to make sure students know and understand how a specific thinking strategy is done. This would enable students to know the importance of such a thinking strategy and make sense of the data collected during scientific investigations.

In the STEPS, various thinking tools were incorporated, such as the *Let's Ask* list, modified thinking maps, self-reflection, and metacognitive logs. For instance, the *L et's Ask* list suggests that teachers make students list down questions or problem statements about the properties of materials they were investigating. There were recommendations on what teachers could do with these questions or problems and how to use them as opportunities to scaffold students' inquiry learning process (Huang, 2015).

HQP, one of components in the habits of mind framework, elaborates that learning is not solely about the acquisition of thinking skills. It should include the art of asking questions and posing problems, sharing thoughts with peers, and collaboratively analysing science concepts that demand a sustained interest in thinking (Costa, 2022). STEPS through its educative features had included ways on how teachers can encourage students to ask questions and pose problems through their thinking tools. STEPS also shows ways for teachers to make students to work together through groupwork and invite teachers to use cues and metacognition skills to sustain interest in student thinking.

All materials were localised to suit Malaysian students. For example, the famous snowman cartoon concept by Keogh and Naylor (1999) was replaced with Malaysian ladies using pots to cook. The STEPS were given to five experts to review for content, language and pedagogy viability. The STEPS was amended based on the experts' reviews and was sent again for final review before implementation.

METHODOLOGY

This study employed an exploratory qualitative research design. The research design helped gain insights on how science teachers up-took the suggestions and recommendations in STEPS to implement HQP among Year 4 students. We were especially interested in how the educative features that focus on HQP were used by teachers and how these features supported teachers' teaching practices.

Sample

Suzana, Rosni and Hisham were teachers who participated in this study. They were also among the teachers who participated in our needs analysis phase. All of them were science education graduates with less than two years of teaching Year 4 science. They volunteered to participate to learn how to develop students' thinking skills. Suzana was the Head of the Science Panel. Her students were high achievers from a new urban residential area near the school. Rosni did not hold any position in her school and teaching students of lower ability. Her students were generally passive. Hisham was the Examination Secretary, and despite his busy schedule, he volunteered to participate. His class consisted of mixed-ability students.

Data Collection

The data primarily came from classroom observations, open-ended interviews, and document analysis. Classroom observations consisted of audiotaped lessons and field notes. The audio recorder hung around the teachers' necks to capture conversations that might be overlooked during classroom observations. All teachers were observed eight times for two months to complete the topic – Properties of Matter. Each classroom observation was one hour. The open-ended interview was carried out to clarify practices observed during the lesson. The teachers were asked to share their thoughts about their practices and the influence of STEPS in the preparation of their lessons. Students' work, such as worksheets, *Let's Ask* list and thinking maps, were collected. This was conducted for triangulation purposes with other sources of data – lesson plans, teacher interviews, and classroom observations.

The STEPS were given to the teachers two weeks before the data collection. As mentioned earlier, STEPS encompassed three aspects: knowledge of skilful thinking, skilful thinking implementation, and classroom management and group discussions. STEPS was designed with detachable sections for the three aspects for ease of mobility and reading. Not to overwhelm the teachers, the third aspect (classroom management and group discussions) was first given to read as teachers were more familiar with problems associated with classroom management. A week later, teachers were given the remaining two aspects of STEPS. They were asked to read the STEPS and see how they would adapt and adopt the educative features to implement skilful thinking in their classrooms. Throughout the duration of the research, researchers' input was minimal. Three weeks after receiving the STEPS, classroom observations commenced as teachers began to teach the topic of Properties of Matter.

Data Analysis

Teachers' enactments were compared with the educative features. Tracers were used to identify evidence of the teacher's practices based on recommendations or tools in STEPS. Tracers were first used by Duncan and Frymier (1967) and later by Bismack et al. (2015) to identify how concepts within written curriculum materials were modified and used. Tracers were vocabulary or actions recommended in the educative features and were evident in classroom practices through observations. Teachers' uttered phrases and cues, teachers using artefacts like thinking tools, and students' worksheets were constantly compared with STEPS. We looked for the fidelity of teachers' practices with STEPS. These tracers then become an analytical tool to inform our coding scheme directly. For example, all teachers used the thinking tool - *Let's Ask* list. We also traced practices that were modified from vignettes in STEPS. For instance, in EF8, a fictional teacher was designed to provide ideas on how teachers can use students' questions to initiate short impromptu discussions among students. The fictional teacher, *Ms Mala,* acknowledges the questions and invites other students to respond by sharing their thoughts about the question. We observed similar practices with these participating teachers.

We developed a matrix by entering interview coding and tracer coding to analyse for patterns within each teacher's use of educative features and their enactment of HQP (Miles & Huberman, 1994). If the teacher had used a particular tool or suggestion once, there shows a fidelity between the STEPS and teacher enactment. The two researchers looked through the matrix, compared and discussed teacher enactment with STEPS. Evidence of the teacher's uptake of STEPS for each theme was determined based on classroom observation, interview data and student work by the two researchers until consensuses were reached. Three main themes emerged from the analysis. They were:

1. Providing tools recommended in STEPS to engage HQP and group work.
2. Implementing HQP – encouraging students to ask questions, modelling better questions, and illustrating how to pose problems.

3. Providing rationales why HQP is important (refer to Table 1).

The final analysis was peer-reviewed.

Table 1. Evidence of tracers of HQP implementation during observation

Themes	Fidelity with STEPS	Suzana	Rosni	Hisham
Providing tools recommended in STEPS to engage in HQP and group work	*Let's Ask* list	√	√	√
	Modified Thinking Map			√
	Group discussion tags	√	√	
Implementing HQP	Encouraging students to ask questions	√	√	√
	Modelling better questions	√	√	√
	Illustrating how to pose problems	√	√	√
Providing rationales why HQP is important	Explain to students the importance of asking questions			√

FINDINGS

The findings showed that the teachers took up the educative features in STEPS. They did not adopt all the ideas in the educative features but rather picked and chose, depending on their needs. Three main aspects showed fidelity between suggestions in STEPS and teacher enactment.

Providing tools recommended in STEPS

The tools recommended in STEPS that were evident in teachers' HQP practices were *Let's Ask* list and Modified Thinking Maps. All teachers used the *Let's Ask* list. Hisham took the time to write down students' generated questions on the whiteboard. He was not judgemental but acknowledged and appreciated students' questions. Eventually, Hisham did not even need not remind his students to write down questions on the *Let's Ask* list. They wrote down questions about what they observed or discussed, creating a space for students to feel comfortable asking questions. These practices were similar to Suzana and Rosni.

> Rosni was surprised that her students could use the *Let's Ask* list to generate questions.
>
> Rosni: This is another good question – Why isn't pen made of wood? … like pencil made of wood?
>
> (Rosni, Classroom observation)

As teachers used the *Let's Ask* list, they discovered that some students were asking good questions. This motivated the teachers to include the *Let's Ask* list in their lesson planning. Teachers also constantly reminded students to list questions before, during and after lessons.

Hisham used the thinking map with cues ("Did I make the right choice?" and "What other materials can I use to replace this material?") from STEPS to focus students' thinking on selecting materials. The thinking map contained questions about their proposed problem and the solutions they could think of. Rosni and Suzana used the tools, but they were for various aspects of skilful thinking, which is not in the context of this study.

In EF9, the roadblock stated that teachers might anticipate problems managing group discussions and teamwork. STEPS suggested that teachers set ground rules and provide tags with written duties for each student in a group. Suzana used the ideas from STEPS to create tags for her students.

> Students were wearing their tags. Group leader delegates tasks to members …
>
> (Suzana, Classroom observation)

Similarly, Rosni took STEPS's idea and constantly reminded the students to do their duty for the group. For example, in classroom observation, Rosni reminded the timekeeper to check on the time for each group as they presented their designs.

> Rosni: Each group gets 5 minutes to discuss how to present your design. Timekeeper, do you have your stopwatch?
>
> (Rosni, Classroom observation)

Implementing HQP

Encouraging students to ask questions

Teachers selected students' questions, discussed them with the whole class and appreciated students for posing good questions.

> Rosni: This question is from Group Earth that will make you think out of the box. The question is … why the tube of the stethoscope is made of rubber? What do others think?
>
> (Rosni, Classroom observation)

The cue that states "will make you think out of the box was taken by Rosni on the idea in EF8 or *Ms Mala's (Fictional Teacher in STEPS)* as a way of appreciating students" questions and discussing them with others.

In one of Suzana's science classes, the students were presenting their prototypes. The group presenting had justified the selection of materials for their design (a house with battery-operated bulbs made from paper and plastic). Suzana allowed other groups to pose questions and problems about the design without intervening.

Presenter: The lamp is waterproof, so if water flows on the roof of the design, nothing will happen.
Student 1 (ask): What if the water hits at the sides? .
Student 2 (ask): But, what if the water flows on the roof?
Student 3 (ask): …if it flows on the roof, the water will flow on the battery, then it would spoil.
Presenter: If the battery gets spoilt, we can still open it (the compartment made of plastic) because it is made of waterproof material.

(Suzana,Classroom observation)

Only after a series of questions posed by students did Suzana interrupt to ask her questions.

Suzana: My question is that … what is the exact function of this lamp house?

(Suzana, Classroom observation)

Hisham used the student's question to prompt a discussion. He read out his student's questions.

Hisham: Group 3 asked a question… 'Can a pencil absorb water or not?'… Okay, put the pencil into the water, and hold it on the top…what can you observe?
Students: wet
Hisham: So, can it absorb water?
Students: Can

(Hisham, Classroom observation)

When Hisham discussed the question posed by Group 3, he got to know students' misconceptions. The students claimed that pencils could absorb water because they were made from wood. Though the students had observed water droplets as the pencil was covered with a layer of waterproof material, they claimed it was wet.

During an interview, Hisham said he was glad he encouraged his students to pose questions because he could identify misconceptions.

Hisham : I'm glad that I asked students their questions. … I got to know they had misconceptions about the pencils…

(Hisham, Interview)

Modelling better questions

Teachers modelled how to ask questions to help students generate better quality questions. When Rosni's students asked questions that were not of higher-order thinking, she proposed ways how students could improve their questions.

Rosni: Ask questions like … why it is not of wood but plastic… or why is it different (materials) for scissors… this is how you ask questions.

(Rosni, Classroom observation)

During a lesson on investigating materials that allow light to pass through, Hisham asked a group of students to read out their question. He realised the question was unclear. He sought clarification and improved on that question.

> Group 6: Why does the plastic bottle light up?
> Hisham: Ok, …that plastic bottle lighted up or …what does that mean?
> Group 6: Because it lighted up when shined with light…
> Hisham: So, your question is…why does the plastic bottle light up when shined with light?
>
> (Hisham, Classroom observation)

Illustrating how to pose problems

When asked to pose problems, students come up with imaginative solutions instead of real-world problems. For example, in Rosni's class, a group planned to design a flying broom to help homemakers clean their houses. They had drawn a device; a broom that could fly, claiming that cleaning would be faster. So, Rosni illustrated by using cues (EF7) how they could decide on a real-world problem and a realistic solution for it. Instead of outright stating they were wrong or providing some solutions, Rosni assisted them by asking probing questions or cues.

> Rosni: …like your friend here wants to help his mother to clean the house, so think of a device that can be used?
> S: Broom
> Rosni:…A broom is one of them…, others?
> S: Feather duster
> Rosni: now think if you want to combine the broom and feather duster, how would you want to do it (combine)…?
>
> (Rosni, Classroom observation)

Hisham kept providing auditory cues for students to think about the choice of materials for their designs, as suggested in EF6. In one of the lessons, Hisham was trying to make students carefully consider what and why they wanted to design the proposed objects.

> Hisham: What are you designing?
> Students: A clock
> Hisham: A clock? You have to decide if there is a need to design a clock.
>
> (Hisham, Classroom observation)

Hisham wanted his students to justify and provide good reasons for their design. This may instigate students to review their choice of object and change their decision to build another object.

> Student: I think we better change our mind; we want to make a bus.
> Hisham: Why bus? There are many buses around, right?
> Students: Yes, there are many buses around, but they don't come here.

Hisham: Why do you want to design a bus that comes here?
What is the purpose? You must think of a problem that you can solve by designing something…

(Hisham, Classroom observation)

Suzana modified the 'onion problem' from STEPS (EF6) to the one illustrated below.

Suzana: My problem is…. I have too many identical boxes. When I needed to keep my things, I had to open each box to see what was in the boxes. I arranged the boxes for stationery, papers, and coloured pencils, so I had a problem opening them one by one to put my things. This is my problem.

(Suzana, Classroom observation)

She explained that it was an actual problem worth solving and asked students to suggest solutions for her problem. Students told her to use a transparent lid, a glass box and to make a hole. To further stimulate thinking, Suzana asked if using a transparent lid could solve her problem. This cues students to examine if their suggested solution solved the problem. The student elaborated that plastic is transparent, and it would be easy to identify things in the box by just looking through the top.

Suzana probed further. Since both suggestions—glass and plastic—are transparent, Suzana mentioned a different parameter for students to compare for the best choice. She stated that glass might be heavy and difficult to carry around. She provided cues for students to think about which materials were most suitable and decide on materials to design an object that solved the mentioned problem based on their properties.

Suzana: …so we need to decide if we should use glass or plastic…glass may be heavy and difficult to carry around, right? Plastic?

(Suzana, Classroom observation)

Supporting students on why they need to engage in HQP

Hisham explained the importance of asking good questions, provided the rationale for questioning, and acknowledged the characteristics of good questions.

Hisham: Okay, my question is, **why do we need to ask questions?**

Students:To understand easily… so we can think… so that we will be smarter… so that we can analyse questions… (multiple answers)

Hisham: Okay… throughout your activity on designing your creations, **how did it (questions) help you? Did it help you to think** and come up with selections of materials… **what did you think about first?**

(Hisham, Classroom observation)

As we analysed the *Let's Ask* list, we found a general improvement in student-generated questions. In the beginning, students asked questions that required basic information like "What is the material to make cork?" or "What is glass made from?" Gradually, they have come up with questions corresponding to the skill of analysing information and ideas, such as '*what if*, *why* and *how*'. Examples of students' questions included "What if the water rises?", "why does cotton cloth absorb water?" and "how does light form shadow?"

As STEPS encouraged students to ask questions, the teachers found students engaged and practising student-centred learning, a recommended 21st century teaching and learning.

> The engagement of my students now… I think this [STEPS]is student centred… I want to show them that this is 21st century learning.
>
> (Rosni, Interview)

Hisham added, "it was easy to adopt these [while showing the fictional teachers in the STEPS] compared to other books". Similarly, Suzana believed that STEPS offered teachers the opportunity to learn about Skilful thinking and how to implement the skills in the classrooms.

> If teachers cannot do it, surely students will not be able to think because teachers are the initiator… when I look at this module [STEPS], I realise that teachers must be prepared first.
>
> (Suzana, Interview)

DISCUSSION

The findings showed fidelity between the ideas of HQP in STEPS and teacher implementation. Using cues suggested in STEPS, the teachers focused on students' HQP and learning as a process, not a product. For example, the selected teachers uttered cues to engage students in HQP, thus creating the prerequisites for students to reflect upon their HQP and how it had helped them improve their thinking. This can be contrasted to the initial practices where teachers asked most questions and manoeuvred students to the right answers.

As a heuristic educative material, STEPS was used solely to scaffold teacher learning with minimal interactions with the researchers. Such materials created space for teacher empowerment in adapting new instructional strategies (Beyer & Davis, 2009; McKinney et al., 2009; Shu et al., 2012). Even though no training was given, all teachers promptly used the *Let's Ask* list. As questioning is one of science teachers' fundamental strategies in teaching (Chin & Osborne, 2008; Jacobs & Renandya, 2021), teachers seem to 'steer' towards using certain aspects of the curriculum materials in their lessons (Remillard et al., 2019). Teachers could see the applicability of the *Let's Ask* list. Knowles's adult learning theory suggests that adults must see the new learning as relevant to their job; only then they are motivated to pursue that course of learning.

Arias et al. (2016) stated that teachers found certain educative support more helpful than others. We found evidence of this in teachers' implementation of STEPS, where teachers used the features differently, leading to different learning outcomes for teachers. For example, Suzana adapted the material in STEPS to a box problem. In comparison, Hisham used cues suggested in STEPS to guide his students to pose better problems and find suitable solutions. Thus, it is important to monitor teachers' use of different educative features because they can allow us to tailor better support for teachers.

The content of the educative material and teacher characteristics are crucial for successful implementation based on the participatory relationship (Remillard, 2005). In our study, we saw that a third player is equally important for the success of the curriculum material – the students. Teachers adapted the suggestions in STEPS based on their students' needs. Guskey (2000) claimed that teachers were willing to change their practices only if they saw positive student learning outcomes. Teachers must get acknowledgement from their students that they (the students) cognitively and affectively approve of the changes. Thus, curriculum developers must provide suggestions on how students' personalities and capabilities interact with the content recommended.

Each curriculum material must be contextualised to its own educational culture; thus, it is not advisable to embrace curriculum materials from other countries. In our STEPS, we used Malaysian ladies using pots for cooking instead of the snowman cartoon concept proposed by Keogh and Naylor (1999). Our roadblocks were problems and challenges faced by local teachers in implementing the skills. Asian cultures are often associated with Confucian values and sometimes contradict some Western-based pedagogies (Pham, 2014). It was found that values stay at the inner layer of teachers' and students' mentality and are not easily altered or removed. Therefore, it would be wise for heuristic curriculum developers to embed local students' learning practices in their curriculum materials (Pham, 2014; Phuong-Mai, 2008).

This study shows the impact of teacher implementation of HQP and some indication of students metamorphosing from passive learners to individuals that ask questions. The findings reflect the habits of mind – where students have a questioning attitude and develop better questions to produce data that can solve problems (Saunders-Stewart et al., 2012). When students ask questions, it piques their interest and curiosity about science (Cairns & Areepattamannil, 2019). This positive student learning outcomes can boost students' retention in the STEM stream, which is a major concern in Malaysia, where the low ratio of students retaining in the STEM stream (Razali et al., 2018) as well as in the Asian region (Wahono et al., 2020). This is because the habits of mind, and particularly HQP, develop students' transferable skills to solve unimaginable problems that students may face in careers that have not been invented yet.

This study captured how three teachers adapted educative features in STEPS; there are limitations. Firstly, we did not empirically study the effect of individual educative features on student outcomes. Secondly, we did not follow up with teachers after the research duration, so it is unknown if these teachers continuously interacted with STEPS and if there are any additional learning opportunities from the materials. In terms of future research, we should investigate how teachers learn by enacting the educative features in STEPS and how that learning influences their future practice. It is also important to ask questions like the impact of educative features on student learning.

CONCLUSION AND IMPLICATIONS

Our findings exposed a fidelity between STEPS and teacher implementation. However, the teachers' usage and adaption of the materials varied. There are several important implications of the study. The first implication is for teachers. Teachers can be agentic and take the opportunity to be self-driven. The heuristic design curriculum material seemed like a more sustainable model for teacher change as it could promote conceptual change among teachers about teaching (Arias et al., 2016; Davis et al., 2014) and how their uptake ideas from such materials can positively change their practices (Arias et al., 2017). Thus, teachers must be open to taking charge of how and when to use curriculum materials.

The second implication is for school leaders. They should anticipate that teachers will have questions and concerns as they interact with these curriculum materials. Thus, school leaders should put support in place, such as professional learning communities, resources, and time to answer teachers' questions and support teachers in making productive adaptions (Zuber & Altrichter, 2018).

The third implication of the study is for researchers. It can be suggested that developing educative curriculum materials as a teacher-researcher partnership so that more aligned and useful support for teacher learning is possible (Trinster & Hughes, 2021). Through this partnership, researchers can anticipate ways in which the teachers might adapt the curriculum, considering teachers' interaction with many materials such as textbooks and tests. In this way, researchers might be able to better support teachers to make more successful or productive adaptations.

The fourth implication is for teacher educators and professional development developers to do more to support what researchers call a teacher's pedagogical design capacity' – that is, the teacher's ability to critique and adapt curriculum materials to achieve productive instructional ends (Brown & Livstrom, 2020). Stimulations and real-world experiences on how to adapt curriculum materials must be included in these programmes.

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