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How can I improve my practice as a science teacher through the development of my pedagogical 'inquiry' skills?

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Abstract

Since my days as a novice teacher, I have always asked myself: 'How do I improve what I am doing?' When I started my doctoral studies, I engaged in critical reflection and reflexivity on my pedagogical practices, and, in the spirit of Alice in Wonderland, became *"curiouser and curiouser"* about 'inquiry' and why it requires a prominent position in my practice. It tells the story of the development of my knowledge, understanding, and educational practice as I researched to improve my pedagogical 'inquiry skills'. This article builds on my doctoral studies. The process of writing this article has enabled me to develop my understanding of Living Educational Theory Research, drawing on my Action Research work, and share my explanation of the importance of conducting it. Using my lived experiences of my doctoral studies, I narrate what I have done to explore and answer questions, with particular regards to pedagogical practices of inquiry in my home country of Malaysia. This article explains how, my epistemic beliefs and values, pedagogical knowledge, and practices as a science teacher improved. I now see myself, as a teacher-researcher, working towards and living my values, and recognising the impact that this has had on my current practice as a teacher educator. I continue to reflect upon, question, and evaluate what I do as I constantly seek to live my values in my practice.

Keywords: Pedagogical practices; primary science education; doctoral studies; living contradictions; living theory; Living Educational Theory Research

Prologue

I have used Living Educational Theory Research as an innovative approach to professional development and growth for teachers' pedagogical practices (Huxtable & Whitehead, 2021). It is based on the premise that an individual's educational experiences are the foundation for their ongoing development as a practitioner (Bigger, 2021). As I embarked on my doctoral studies in 2014, I brought with me a range of beliefs related to my pedagogical practices as a science teacher that reflected my ontology and epistemology at that stage of my life. Thus, at the start of the study, through my own reflections, I highlighted some key issues that needed to be addressed.

In the context of my own practice, the 'where I was at' component, referred to as reconnaissance (derived from the French word, *reconnaitre*: to look at), was particularly significant. Elliott's (1991) model identifies the reconnaissance phase as a starting point for clarifying one's concerns and developing them into more focused questions and hypotheses. Significant unintentional reconnaissance had already occurred in the period prior to this study. So, in order to identify any change in my practice, I considered it was vital to discover my starting point as a basis for critical reflection. At first, this was a challenging endeavour. It was worthwhile, however, as it allowed me to identify my motivations for this study and its relationship to my research interests. I now realise that my reflections took me beyond the reconnaissance practice and divisions of Maxwell (2003) and into an 'I-focused' form of educational action research (Glenn et al., 2023). The outline of my reconnaissance phase provided me with a realistic assessment of where I was, what I hoped to achieve, and how I thought I might do so. I was beginning to use aspects of first-person action research.

As a primary school science teacher, I began to question the centrality of inquiry in relation to science teaching. "Am I teaching science as through or with inquiry? What does inquiry look like in primary schools? What are teachers' goals when using inquiry? Does inquiry result in better learning?" This reflection was initiated through the cognitive processes of both "problem finding" and "problem-solving" (Leitch & Day, 2000, p. 180). I then started to refine my thinking, on the basis of constraints I encountered in implementing inquiry teaching in the past, keeping in mind Kemmis et al.'s (2014) central question: "What aspects of your practice will you change?" (p. 102)

In a recent publication (Shaik-Abdullah et al., 2023) I co-authored on Living Educational Theory Research, I make explicit my latest understanding of this research. This has implications for my practice as a teacher-researcher as I generate my living-educational-theory. The implications are focused on clarifying and communicating the meaning of the embodied values I use to distinguish my practice and my learning as educational. In this article I show what these implications have been. I clarify my embodied values, which have emerged in the course of my Living Educational Theory Research, that form my explanatory principles in my explanation of my educational influences in my own learning, in the learning of others and in the learning of the social formations within which my practice is located.

The reconnaissance

I have published a detailed discussion of my reconnaissance phase in *"Curiouser and curiouser!"*: A reconnaissance of my doctoral studies as a 'teacher-researcher' (Mat Noor, 2022a). In this reflective article, I illustrated how I became a 'teacher-researcher'. I employed two dimensions of reconnaissance – 'unintentional' (the exploration of my beliefs and behaviours) and 'intentional' (the exploration of the research context, investigation approaches and the literature) – to explore). Using this approach, I will now show how I explored my beliefs and experiences in the early stage of my study, as well as literature related to my research interests: inquiry-based teaching in the primary science classroom.

Throughout this article I continue an unintentional reconnaissance approach as I now critically engage with my postgraduate data, which was gathered during my international studies. I explore the relationship between my beliefs and the actions I took. This has helped me to move my thinking from Action Research towards Living Educational Theory Research and so clarify my values of 'inquiry' and 'education' as my standards of judgement and explanatory principles in my account of my living-educational-theory.

My appreciation for science investigation began during my secondary school education. I was fascinated by the subject of science and felt drawn to understanding the natural world through systematic investigation and experimentation.

My early experience set the foundation for my passion for 'inquiry' and my belief in the importance of hands-on and interactive learning experiences in the classroom. In addition, my early education in science left a lasting impression on me and motivated me to become a teacher. I was determined to not repeat the same teaching methods as my own science teachers and instead strive to make science education fun, interesting, and engaging. I firmly believe that science should be taught in a way that sparks curiosity and encourages hands-on exploration, experimentation, and discovery. This is the most effective and engaging way for children to learn science and was in line with my beliefs about how new knowledge is created through inquiry that is educational.

As a qualified primary school science teacher, I was aware of how important inquiry is and I was often encouraged to implement it in the primary science classroom. However, during my undergraduate and teacher education training, I was given little knowledge as to how inquiry should actually work in science teaching. I think the term 'inquiry' itself has been misleading in its own terminology in Malaysia. What I understood about 'inquiry' is '*sifat ingin tahu*', literally to be 'inquisitive', and I suspect my school colleagues understood 'inquiry' in the same way.

I imagine that there may be a discrepancy between what I and some of my colleagues understand as 'inquiry' and what is outlined in curriculum documents and literature. This could be seen as an epistemological clash, as the differing perspectives on what constitutes 'inquiry' may lead to varying approaches in the classroom. While curriculum documents may provide guidelines and requirements for teaching science, they may not fully capture the essence of inquiry-based learning. In Malaysia, curriculum documents advocate learning science through the process of inquiry across many jurisdictions (MOE, 2013, 2014). The science curriculum defines inquiry as "generally a means to find information, to question and to investigate a phenomenon that occurs in the

environment" (MOE, 2013, p. 10). It also emphasises that an "inquiry approach may not be suitable for all teaching and learning situations. Sometimes, it may be more appropriate for teachers to present concepts and principles directly to children" (MOE, 2013, p. 26). In fact, the 'discovery-inquiry approach' has been emphasised in other subjects, too, as a general approach to teaching and learning. Reflecting on this, I now recognise that there were contextual clashes with my values.

Some teachers may follow these guidelines strictly and stick to a more traditional, lecture-style approach, while others may prioritise hands-on experiences and experimentation in order to foster a love for science and encourage children to think critically and ask questions (Triona & Klahr, 2007). My personal perception of 'inquiry' developed from my early career and through engagement with the literature as well as from my studying in a UK context.

At the beginning of my teaching career, my perception of 'inquiry' was that it was just one of the many methods/approaches one could use when teaching; I did not yet see it as one of the vital elements of teaching science. Literature on science education suggests that Malaysian science teachers require support in planning their science teaching, which can lead to an improvement of their pedagogical knowledge and skills (Osman et al., 2006). This is because "science is still being taught in a didactic manner. A small number of teachers do not conduct experiments with their children and a handful of them concentrate more on demonstration" (Syed Zin, 2003, p. 47).

When I was offered the opportunity to continue my studies at postgraduate level, I chose to study abroad to allow me to understand my inquiry-based pedagogical practices from an international perspective. I will now explain how I have critically reflected on data I gathered from my international research. I started my Master's degree at Brunel University London in the United Kingdom and from that point onwards I explored what is meant by 'inquiry' and became interested to know how it actually works in the science classroom. I started to analyse 'inquiry' and its important place in the National Curriculum for England and my work was published as a book chapter (Mat Noor, 2014b). This data shows how I learned from the literature and policy documents in different settings, which have differing educational values. I came to realise that 'inquiry' is central to the science-teaching repertoire. In the next paragraph I show 'inquiry' as my educational value in action.

I have come to understand that inquiry is at the core of effective science education. Inquiry refers to the process of asking questions, exploring, and discovering new information and knowledge through hands-on experiences, experimentation, and observation. When children engage in inquiry-based learning, they are encouraged to make connections between what they are learning in the classroom and the real world, which enhances their understanding of scientific concepts. By encouraging children to ask questions, make observations, and design experiments, they develop critical thinking skills, creativity, and a sense of ownership over their own learning. This leads to increased motivation and engagement, as children become invested in the learning process and take an active role in their own education.

By clarifying 'inquiry'' and 'education' with 'life-enhancing values' I want to express more fully in my role as a teacher, I'm driven to prioritise holistic student development. This perspective reshapes my curriculum design and pedagogy to foster

student autonomy and deepen my educational relationships with learners. It urges me to continuously grow professionally and shift my success metrics to include aspects like curiosity and problem-solving. Embracing 'inquiry' as a value I hold myself to account to expressing as fully as I can in my practice as a science teacher, I advocate for collaboration and inclusivity and inspiring students to view education as a lifelong, enriching journey.

At times, I was confused by the varied terminology and definition of 'inquiry' as a process. Apparently, I was not alone: there is also evidence of confusion among the broader science education community (Bevins & Price, 2016). I discovered that different countries and scholars introduce different terms such that there is no international agreement on what 'inquiry' means. The Organisation for Economic Co-operation and Development (OECD), for example, has used several inquiry terms in their Programme for International Student Assessment (PISA) reports (e.g., scientific inquiry, inquiry-based/oriented teaching).

In my doctoral studies, I treated the literature review as a springboard for me to develop my understandings and beliefs. But in writing this reflective article I realised that advocacy of 'inquiry' is common in discussions of science education, with inquiry being defined "as 'practised by professional scientists' through a series of procedures" (Bevins & Price, 2016, p. 19). My educational experiences were informing my ongoing development as a practitioner and therefore I was beginning to dip my toes into the ideas of Living Educational Theory Research (Bigger, 2021). I began to ask about the educational basis of curricula. I questioned whether inquiry-based approaches in science should solely emphasise the practices of professional scientists and should not mention the creative and reflective capacities of children (Kamarudin et al., 2022; Schwab, 1962). The aim of the primary school science curriculum in Malaysia does not mention such an aim:

> The aim of the primary school science curriculum is to develop children's interest and creativity through everyday experiences and investigations that promote the acquisition of scientific and thinking skills as well as the inculcation of scientific attitudes and values. (MOE, 2013, p. 2)

The primary school science curriculum in Malaysia highlights key scientific skills, thinking skills, scientific attitudes and scientific values (Mat Noor, 2022b). Although the curriculum aims do not mention 'inquiry' directly, I finally realised that these elements were part of inquiry. The question was, 'do I teach science as 'how scientists do their work' or do I teach children to learn about science as 'how scientists do their work'? The epistemological difference between these questions has grown in importance as I reflect on my research data. As I now can say I value education and inquiry, these must be seen to be part of my approach to teaching and learning and must be seen in how my children learn. Kruit et al. (2018) point out that in primary science, children are taught inquiry by way of learning by doing (science process skills) to acquire content knowledge and epistemic knowledge. Thus, when children are doing experiments, they view themselves as "acting like [a] scientist" in class (Zhai et al., 2014, p. 568).

In addition, while children are engaging in science process skills (e.g., observing, experimenting, measuring and testing), they are also applying thinking skills to make sense of the data and connect their thinking to scientific theories (Osborne, 2015). Besides the curriculum aim, 'inquiry' can also be described as an approach to teaching science (e.g., inquiry teaching, inquiry-based learning, inquiry-based science education). Ultimately,

however, whatever title 'inquiry' is given, it should be defined by what comes under its banner.

I implemented inquiry teaching as a small-scale project to see how it works in primary science (Mat Noor, 2014a). Utilising Collaborative Action Research study as a research design, I collaborated with two teachers in Malaysia who volunteered to implement an inquiry approach in their own classroom using a developed module, which had considered all aspects of inquiry. One of the things I learned about classroom interactions was the importance of how teachers ask questions and how children respond to these questions Effective classroom interactions involve a range of skills and techniques that I as a teacher can use to engage children and promote their learning. One key aspect of this is the way that I ask questions and how children respond to these questions. In the process of conducting my research, I realised that questioning is one of the most important components of inquiry teaching (Harlen, 2011). This new learning for me has gained in importance as I considered what made my action research, educational. According to Whitehead (2018) educational research includes learning with values of human flourishing in developing one's living-educational-theory as an explanation of educational influences in learning. I realised the importance of a focus on 'I' as a teacher and researcher and 'on what I have learned to value as a person and as a professional within my world (Glenn et al, 2023).

Although the children who were involved in my Master's research project were from rural areas, they manifested a high degree of curiosity and asked many questions. Besides questioning, another issue that I was interested in throughout the process was that of control. The idea of letting go and having the children take a more active role in the classroom through inquiry-based learning was somewhat threatening. Using this process, the teachers' role changed. The children became the planners and the teacher facilitated. I knew of this concept in theory (Metz, 2004), but I was not sure how I would handle this situation in practice.

Generally, the results of the project were profound for me, and I was hoping my teaching colleagues would also greatly benefit from the study. However, the inquiry approach was new to them, and often neither had the necessary competencies to utilise it. Yet, one of the positive aspects was that they also had fewer inhibitions in attempting to implement inquiry teaching, because to them any approach was new and they were more open to changing their existing approach. Re-examining my Master's data I found evidence that my research project may have had a significant impact on the learning of others, as in the following reflection of a teacher in my collaborative research

Lesson 1

As I reflect on my teaching, I realise that some of my children seemed uneasy and struggled to comprehend the question I posed to them. However, after repeating the question a few times, they gradually grasped the essence of it and answered surprisingly well. This experience has taught me the importance of delivering clear and concise instructions to my children to ensure their understanding and engagement in the lesson.

Lesson 2

As I improve my questioning techniques, I can see that my children's level of questioning is becoming more structured. They are able to formulate good questions more effectively, and I

am pleased to see that all the questions analyzed by me are of the standard that I am expecting.

Lesson 3

In my third lesson, I noticed that my children generated ideas more easily than before. I was pleased to see that they were engaged and not bored with the planned activity. Throughout the lesson, they appeared very happy, active, and comfortable using the implemented strategies. This made me feel confident in my teaching approach and excited to continue implementing new techniques in future lessons.

Lesson 4

As I wrapped up the final lesson of this module, I felt a surge of confidence in implementing all the strategies and following the plan systematically. It was satisfying to see my children excitedly generate data from the experiments that they had carried out in lesson three. Seeing their enthusiasm and eagerness to learn was truly rewarding.

The teacher reflects on four lessons. In lesson 1, the children struggled to comprehend the teacher's question, but with repetition, they were able to understand and engage. Lesson 2 shows that the teacher's improved questioning techniques have resulted in more structured and effective questioning from the children. In lesson 3, the teacher observed that children generated ideas more easily and were engaged and comfortable using the implemented strategies. Finally, in lesson 4, the teacher felt confident in implementing all strategies and observed the children's excitement and enthusiasm for learning.

While I had evidence of children and collaborating teachers gaining new knowledge from my research project I was concerned about my position in this form of research. Zeni (1998) indicates, academic research conducted by an outsider to improve teaching often has a specific goal in mind; rarely, though, do teachers and children acting as participants in the study benefit directly from the findings. In addition, my biggest frustration with the project was that I was only involved as an outsider researcher and only told the teachers what they needed to do in their classrooms. Since I was an outsider who was peering into their classroom from the shadows, I was not responsible for the children whose learning the teachers documented. I did not have a chance to feel for myself, as a teacher, what it was like to implement inquiry teaching with children. I also thought that I could implement it even better myself than the two teachers did; ultimately, I was not yet feeling the spirit of 'inquiry' in me.

Reflections on the knowledge I created and my understanding of my practice

In the reconnaissance stage, I came to realise that engaging children in inquiry teaching is an essential element of science instruction that helps children develop scientific literacy and provides them with the opportunity to practise important science process skills such as observing, measuring, classifying, comparing, inferring, etc., along with critical thinking and problem-solving skills (Mat Noor, 2021). My experience in this phase made me reflect on the nature of knowledge, my understanding of my practice, as well as the problems I had faced in my previous teaching experiences, and any opportunities for improvement.

As Kemmis (2006) highlights, in order to ensure high-quality practitioner research, researchers must address important problems related to action and thought, both in theory and practice, for the good of each person, societies, and education. This is why I decided to use action research as a method for developing inquiry-based teaching and thus improving my practice as a science teacher. Huziak-Clark et al. (2007) show that the implementation of inquiry teaching improves teachers' pedagogical skills (i.e., the effectiveness of questioning techniques, greater confidence in planning and implementing inquiry lessons, and an increase in content knowledge and breadth of knowledge). Thus, it positively impacts children's conceptual understanding.

I had encountered Action Research during my previous study (see Mohd Salleh & Mat Noor, 2015) and had seen through my own eyes that action research provides an ideal vehicle to accomplish the above goals. As I embarked on my doctoral studies, I wanted a research process that allowed me to be 'in action' and to have a chance to implement inquiry teaching myself. By doing this, I was hoping that my inquiry-based teaching practice could be improved as part of my day-to-day teaching. For that reason, in my doctoral studies, I chose to use a first-person form of Action Research as Elliott (1991 and Stenhouse (1975) describe as a method for improving my practice. I have since gone on to engage in Living Educational Theory Research to explore and answer a core question Whitehead has continually posed, 'how do I improve my practice and generate a valid explanation for my educational influence in my own learning, the learning of others and the learning of the social formation/s which form the context of my professional practice?' In the next section I go onto explicate my living-educational-theory.

Discussion

> Epistemic beliefs are core beliefs, or our individual philosophies about the nature of knowing and knowledge … This includes the knowledge and beliefs that teachers hold about teaching and learning … Epistemic beliefs have also been shown to be related to one's capacity to engage in reflection on teaching and learning. (Walker et al., 2012, pp. 264-266).

In resonance with Walker et al. (2012), I have come to realise that my beliefs about inquiry teaching have undergone a significant transformation during my doctoral studies, and I now have a much deeper understanding of 'value in action' when it comes to inquiry-based approaches. As I stated earlier, when I was a teacher in school, I assumed that inquiry was only one of many approaches to teaching and learning. However, when I completed my doctoral studies, I realised that inquiry is not just an important approach in science teaching, but that inquiry should also be part of the curriculum aims of science education (Anderson, 2002). I came to my doctoral studies not just because of my desire to achieve a higher degree but also because of my curiosity about 'inquiry'.

In the following, I discuss the living contradiction I experienced over the four years of my doctoral studies, by virtue of holding educational values whilst at the same time negating them (Whitehead, 1989). I believe that 'educational' does not only refer to schools or educational institutions, but 'educational' is a process for each individual on how to learn, practising what is learned for the benefit of the world. 'Educational' – as a new understanding of my values, is a continuous process with no end, and it is an important value to be held by an individual throughout their life. By holding these values, in my

doctoral studies, I searched the ways to research and improve my pedagogical practices and used up what I had learned by creating inquiry-based teaching for children studying primary science in Malaysia. It is aligned with the notion of adopting a Living Educational Theory Research approach to realise the educational responsibilities of a professional practitioner to improve their practice and explain "their educational influences in their own learning, in the learning of others and in the learning of the social formations that influence practice and understanding with values that carry hope for human flourishing" (Huxtable & Whitehead, 2021, p. 311).

How my educational research impacted on my practice as a teacher and teacher educator

When I was in my early days of teaching, I felt that my colleagues and I were research targets for university researchers (e.g., we were asked to fill in questionnaires, be interviewed and observed). Later, they published reports and journal articles, and, in most situations, we never got any feedback. Teachers often feel mistrustful and worried that they would be continuously exploited as a research tool (Zhou, 2012). I agree that teachers have not been treated entirely ethically in some research studies.

Although the idea of educational research is primarily to provide a knowledge base and expertise to support effective teaching and learning, I did not feel my teaching practices were informed by research when I was in school. It is plausible that teachers are unlikely to think that they can effectively use the outputs of educational research to improve their teaching. It is therefore not surprising that the researchers, in Speight et al.'s (2016) study, found no evidence to suggest that participating teachers were more likely to use research to inform their teaching than they were before the study commenced. Therefore, I realised that a contradiction exists, as educational research is not something that my teaching colleagues or I use in our everyday teaching practices.

In my early teaching career, I found that research articles that my colleagues and I read tended to be written for an audience of other researchers rather than for us as teachers. We were not reluctant to read these materials, but rather we were not given guidance on what materials would be of most relevance to our practice. Furthermore, not many resources or open access materials were provided. I still feel the biggest hurdle to teachers implementing research is just how difficult research articles are to read. It is not because researchers leave out content that teachers want; rather, all too often, researchers write in a language that makes it hard for everybody, including academics, to understand. This is even harder for teachers, who want streamlined descriptions and practice-based solutions. Therefore, journal articles, theses, and other published materials such as reports about evidence-based research were not useful for other teachers or for me.

Furthermore, teachers are busy, and they do not have enough time to study research evidence and articles (Speight et al., 2016). The question of teachers' workload has been a never-ending issue in Malaysia. Malaysian teachers complain about having so much administrative work (e.g., planning strategies, writing reports, keying in information online) that they have little time to devote to teaching in the classroom, let alone doing research (Syed Hassan, 2018). Although we organised a professional development programme once a

fortnight when I was a schoolteacher, such programmes were run by an inexpert teacher during the evening time after school and were not based on research.

When I started my doctoral studies, I had a very clear view that educational research cannot be done by someone whom we call an 'outsider'; the teachers themselves can best carry it out, as it must have an impact on classroom practices. I used the form of Action Research proposed by, for example, Coghlan and Brydon-Miller (2014) and Kemmis et al., (2014) as one of the central tenets they focus on is that only teachers can change their practices in their own local settings, even though they may have been influenced from elsewhere. However, my broad knowledge of values-based education, acquired across diverse settings and cultures, has the power to transform both my practice and me.

In conventional research, a literature review "acts as a springboard into the researcher's own study, raising issues, showing where there are gaps in the research field, and providing a partial justification for the research or a need for it to be undertaken" (Cohen et al., 2017, p. 227). I had been exposed to substantial literature that informed my skills as a researcher and my pedagogical knowledge. I found the literature review interesting and comforting because the more I read, the more I realised how much I did not know. Additionally, it helped me refine my thoughts and focus on my interests. Hence, I have been able to develop my own pedagogical thinking, which includes all the critical aspects of inquiry, and their interconnected relationships.

The Action Research methodology I used offered me invaluable insights and tools, benefiting not only my investigative approach but also augmenting my pedagogical acumen, thus enabling me to construct a comprehensive understanding of the crucial elements of inquiry and their interrelationships. As Elliott (1994) asserts:

> Action research leaves a role for the educational theorist in the university as a supplier of theoretical resources for teachers to use in reflecting about and developing their practice, but it establishes the teacher as the ultimate arbiter over what is to count as useful knowledge. It is the teacher who decides the extent to which theory misrepresents educational practice. (p. 137)

I wanted a research methodology to move beyond Elliott's ideas. I had already developed a deep understanding of the importance of inquiry in science teaching and learning and therefore the research process I chose needed to address the challenges of the research processes I have outlined above. I now know that I needed a form of research that can establish the teacher as the ultimate arbiter over what is to count as useful knowledge. In my doctoral studies, the methodology I selected equipped me with the ability to make informed decisions based on sound practical and theoretical knowledge. It also enabled me to transform both my practice and enabled me to be a theorist by developing my own living-educational-theory.

A criticism of teacher research, with which I would disagree, is that it is more focused on practical relevance and less on generating knowledge about teaching and learning (Admiraal et al., 2017). In contrast, Thompson and Perry (2004) argue that the findings from one particular Action Research project can be generalised to several other similar situations. If what happens in the classroom is seen as part of the change process for both teacher and child, teachers are not only agents for change within the classroom but also for society as a

whole (Bourn, 2016). This aligns with the central tenets of Living Educational Theory Research, which emphasise the importance of individual and collective agency in creating positive social and educational change (Whitehead, 2018).

For me, theories can take different forms. The 'usual' form (normally accepted in academic contexts) is an abstract theory (i.e., ideas abstracted from real life). My doctoral studies employed the not-so-widely accepted form of people's personal theories of practices (i.e., theories grounded in practices). These theories of practices are generated from practical forms of inquiry like Living Educational Theory Research, which enable them to investigate and evaluate their work (Whitehead, 2018). Thus, Living Educational Theory Research, as I now understand, is more than a methodology: it is about creating new knowledge and generating theory, including values as explanatory principles.

How do I teach 'science'? As a process or content or both?

The effort to improve my pedagogical knowledge of inquiry-based teaching did not only depend on my engagement with the literature but also my reflections on actual practice. To address the latter, during the first year of my doctoral studies, I attended various continuous professional development (CPD) courses in the UK for primary science teachers. Courses included 'Moving from Enquiry to Working Scientifically', 'Assessment and Progression in Primary Science' and 'Working Scientifically in the New Primary Curriculum'.

Initially, these courses helped me understand how inquiry works practically in the science classroom. I was informed about how to carry out inquiry activities with children, including assessments in primary science. Through these courses, I developed initial ideas on how to integrate the 'theory' as outlined in the literature review into practice. I also developed many ideas as to how to develop my own teaching strategies in teaching and learning primary science.

Most of the courses were practical in nature, which enabled me to explore the concept of inquiry in more detail, through hands-on activities. However, the more I attended such courses, the more questions arose in my mind about 'inquiry'. Indeed, I began to question my understanding of 'inquiry'. Did it refer to the practical activities and experiments suggested in the CPD courses I had attended and, as outlined by authors in the literature review, or was there more to it?

One of the CPD courses I attended was about 'various types of scientific inquiry'. I was exposed to many ideas about activities such as 'exploration', 'identifying and classifying', 'observing over time', 'pattern seeking', etc. Each type of 'scientific inquiry' was introduced both in theory and through practical activities. For example, facilitators conducted 'identifying and classifying' activities that involved sorting objects or events into groups. In this activity, other participants and I were directed to isolate various types of English biscuits using the decision-making tree diagram approach (dichotomous keys), as shown in Image 1. We were required to write polar-type questions using the eight types of English biscuits provided, such as *custard cream*, *Jammie Dodger*, *chocolate digestive*, and *Oreo sandwich*.

Through questions related to the criteria of biscuits such as, "Is it round?", to start with, we then asked questions such as "Does it have chocolate?", and "Does it have a filling?" to expand the tree branches. Finally, we achieved the conclusion by classifying

biscuits according to the physical criteria based on our observations. We also compared these results with other groups and found that, in fact, they used different criteria. I believe that this activity not only focuses on one particular inquiry skill, 'identifying and classifying', but also requires the learner to have the skills to make observations, ask questions, and come up with the best possible variables at the same time.

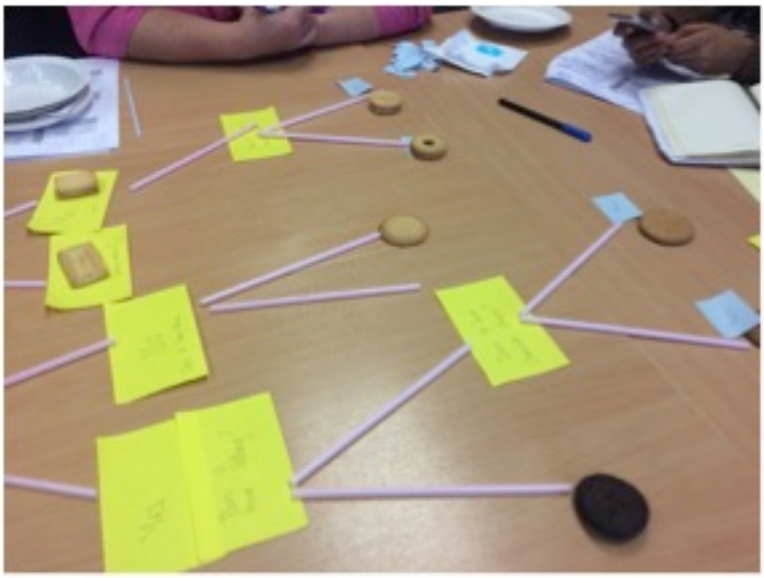

Image 1. Decision-making tree diagram approach (dichotomous keys) for classifying activity.

The above observations resonate with Rillero's (1998) questioning:

> Which is more important, science process skills or content knowledge? Science process skills drive the doing of science; science content is the knowing of science. How teachers answer this question can have dramatic implications for the science experiences that they choose for their children. (p. 3)

Without a doubt, I learned a lot through the CPD course, and the practical activities that were carried out as above are part of inquiry-based science process skills. I also thought about how these skills can be practised in my context: Malaysian schools. The method of 'inquiry' I learned about was related to how to teach the 'science process'. The primary science curriculum in Malaysia, however, is structured using learning themes (e.g., human life process) and science topics (e.g., human respiratory process, human excretion, and deconstruction). There is no emphasis given to teaching science process skills in the curriculum.

I question myself whether I was required to teach 'science process', 'science content', or both? My engagement with the literature made me realise that "science content and science process skills are equally valuable; the learning of one aids the learning of the other" (Rillero, 1998, p. 4). However, further questions arise: how do I integrate science process skills in my teaching, given that it is structured around science content? How could inquiry (especially science process skills) be fitted into the primary science curriculum in Malaysia? I found that these were great challenges for me. In grappling with these challenges, I considered various teaching methods and their potential to support inquiry and

science process skills, leading me to ponder, ‘Can the cookbook method of practical activity be considered a form of ‘inquiry’’?

Can the cookbook method of practical activity be considered a form of ‘inquiry’?

In the second year of my doctoral studies, I was offered the opportunity to participate in an exchange support programme in Japan (see Image 2). I was very interested in the international perspective on science education, particularly in Asian countries like Japan. Japan is one of the countries that has achieved a very high score in science (well above the OECD average) in the Programme for International Student Assessment (PISA), coming second worldwide in 2015 and fifth in 2018. I did not intend to find the secret behind this; instead, I was interested to see and learn how Japanese children actually learned about science in school.

Image 2. Participants of the exchange support programme gather for a group photo after an enriching visit to Japanese schools.

While I was in Japan, I had the opportunity to visit a few primary and secondary schools in Tokyo. I developed knowledge of how Japanese science education works, and I was able to directly observe Japanese science classrooms on an informal basis. One of the things that attracted me about science education in Japan was the structure of its science curriculum, known as the ‘Course of Study’. However, the Japanese Course of Study for science does not provide a description of what the inquiry-based activities are.

In my reflections at that time, I noted science education in Japan, particularly in secondary school, is curriculum-oriented and in all public schools, children and teachers use government-censored textbooks. If the textbooks describe experimental designs and the expected results, children and teachers are more likely to just follow what they find in the textbook.

I also observed Japanese science classrooms, mainly when the children carried out practical activities. I found that practical activities conducted by Japanese children in both primary and secondary school were structured (using a deductive approach). Children were

initially taught about a specific topic and its theory (scientific content), and then they tested the theory by carrying out practical activities. When children were doing practical activities, they were provided with hypotheses and variables; they studied the procedure and followed the steps in the textbook.

My observations of Japanese schools are in line with the OECD's (2012) report, which highlights that Japanese teachers usually follow a detailed plan of how learning activities should be presented, although they act as facilitators in the classroom when children carry out inquiry-based learning. However, I came to a realisation that, although the children conducted a cookbook method of practical activity, they were actually doing something that is referred to as a 'confirmation inquiry' activity – based on the four levels of inquiry (Bell et al., 2005) – and they fully engaged with the inquiry. Confirmation inquiry is a type of inquiry-based learning where people are provided with a question and procedure (method) where the results are known in advance, and confirmation of the results is the object of the inquiry (Toma, 2022). Although they conducted the inquiry at the lowest level according to Bell et al.'s (2005), science process skills such as observation, measuring numbers, interpreting data, etc., were still integrated into the science teaching and learning processes.

Since I was in Japan just for a short programme, I did not speculate as to whether what I had observed was a usual practice in Japanese schools. Most importantly, I questioned, again, whether 'inquiry', which goes to the heart of science teaching (as emphasised in science education literature), can be conducted by simply implementing hands-on experiments and practical activities in the science classroom. Therefore, my experience in the Japanese schools highlighted the importance of designing meaningful and effective learning experiences that align with educational values such as inquiry-based learning. By doing so, learners can develop a deeper understanding of the subject matter and acquire critical thinking skills that are essential for success in their academic and professional lives.

When I returned from Japan, I felt something was missing about the inquiry that I had not yet explored. Inquiry, as I understand it in Japan, was not simply about engaging in hands-on experiments and practical activities in the science classroom. In fact, science education literature has highlighted that inquiry teaching is not as simple as just performing activities such as observing, making inferences, controlling variables, etc.; instead, it is a combination of the more traditional science processes, along with scientific knowledge, reasoning, and critical thinking, to develop scientific literacy (Lederman et al., 2013).

Upon reflecting on the experiences in Japan, I wondered how I might incorporate the multifaceted nature of inquiry into the context of a curriculum-controlled and heavily centralised education system in Malaysia - could there be a place for the 'cookbook method' of practical activity within this model of inquiry, and how could it possibly help empower my children to become active inquirers?

How can I let the children I teach be inquirers in a curriculum-controlled and heavily centralised education system?

In the second year of my doctoral studies, I went through an upgrade process from the Master of Philosophy programme to the Doctor of Philosophy programme. My upgrade

panel questioned me about the role of thinking skills and cognitive processes in inquiry-based teaching. I was very pleased with the feedback and realised that I needed to explore the psychological aspects of inquiry-based teaching, particularly when my clients were children. As Chinn and Malhotra (2002) articulate:

> … many scientific inquiry tasks given to children in schools do not reflect the core attributes of authentic scientific reasoning. The cognitive processes needed to succeed at many school tasks are often qualitatively different from the cognitive processes needed to engage in real scientific research. (p. 175)

Based on this realisation, I started to identify cognitive processes as one of the necessary components to integrate into the science classroom, especially to carry out inquiry tasks. The shift in my understanding of the importance of cognitive processes has profoundly influenced my teaching practices, prompting me to integrate more inquiry-based teaching into my science curriculum. This is essential as the thinking underlying inquiry involves cognitive processes, as indicated by Chinn and Malhotra (2002). For example, when the teacher conducts an inquiry activity such as controlling variables in inquiry-based teaching, children follow predetermined procedures, and class discussion focuses on what to do but not why the task should be carried out in that way.

However, inquiry-based teaching requires children to discuss the conceptual reasons for controlling variables by explaining why they measure certain variables and why they keep one or more variables constant in the experiment (Jin et al., 2016). Based on this concept, it is true that we expect children to master both scientific knowledge and skills. However, the teaching of cognitive processes behind scientific skills is challenging for children, particularly in primary school. I believe that children must learn about inquiry in an appropriate manner, based on their classroom context and their own developmental capabilities.

Based on my curiosity about the role of cognitive processes in inquiry-based teaching, I decided to spend some of my time at Yale University, an Ivy League university in the United States, for an exchange programme (see Image 3). I was very fortunate to pursue my research under the auspices of an educational psychologist. Since analysing children's understanding of how scientific knowledge is constructed is complex and requires research that takes account of both philosophical and psychological aspects, my original intention at Yale was to understand the role of children's cognitive development in the teaching and learning of science. However, as I further delved into the subject matter, I realised that effective teaching requires more than just a solid understanding of cognitive development. As a science teacher, I strive to improve my practice by integrating a variety of teaching strategies that cater to diverse learning styles and foster critical thinking and scientific curiosity in my children.

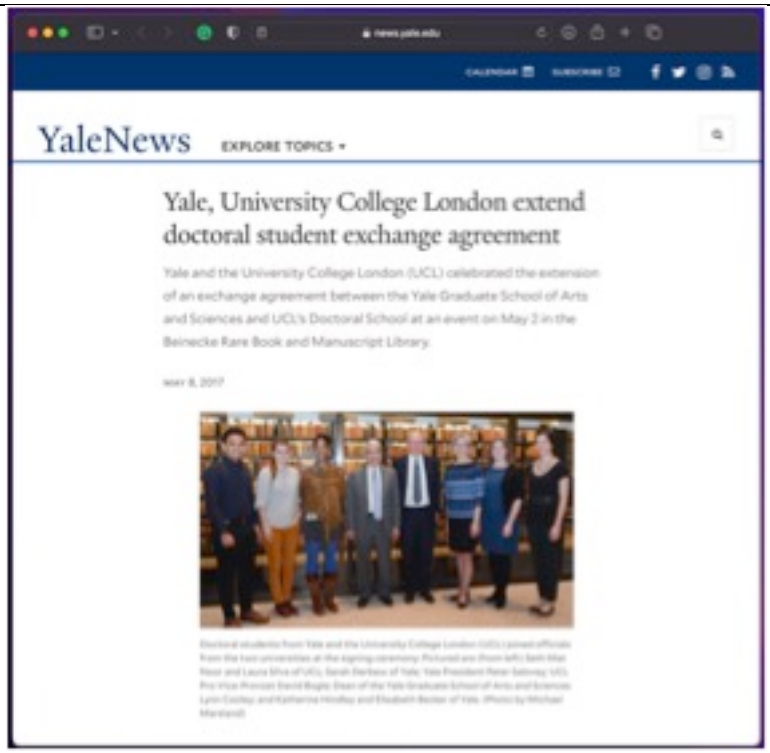

Image 3: Screenshot from Yale News featuring an article on the exchange programme (Yale News, 2021)

The research centre that I was located in is internationally recognised for excellence in clinical practice and research pertaining to children's development, and my exchange programme blended educational and clinical perspectives on working with school-aged children. I spent an allotted amount of time in the classroom (pre-school) by observing the behaviour of children besides learning about teachers' responsibility to provide a creative and exciting environment and curriculum for children.

During my time on the exchange programme, I engaged with the literature, and I learned that young children can be sophisticated scientists (Metz, 2011, p. 68). They are not concrete and simplistic thinkers; they can think both concretely and abstractly. Rather than starting as a blank state, children come to school after years of cognitive growth, whereby they already have gained substantial knowledge of the natural world.

I also had the opportunity to observe children under an educational psychologist's supervision at one of the kindergartens. I spent most of the day, once a week for three months, with a group of five-year-old children. Without any pre-determined objectives and directions, I used naturalistic observation for this purpose. By remaining unobtrusive, I gained access to children's behaviours that were more characteristic, more spontaneous, and more diverse (Wells, 2010). My presence in the classroom was as an external observer, and the children were alerted to my presence before I stepped into their classroom.

By carrying out an 'overt participant observation', I was in the classroom with children, observing their behaviour closely. Some of the potential pitfalls of this approach is that children not behaving 'naturally' as they know they are being watched. Although sometimes there were those who wanted to interact with me when they felt comfortable, I responded to them appropriately as I could. From the first day I was there, I focused on

watching the behaviour of each child when they were playing. Sometimes, I followed some of their movements from one play station to another. Most importantly, I focused my observation on interactions between the teachers and children.

The kindergarten had an interesting educational philosophy. The institution advocated that children learn best when they are actively engaged. After gaining a deeper understanding of the value of education, I now recognise the connection between the philosophical and educational foundation of learning together through practical experience. Based on *The Hundred Languages of Children* (Edwards et al., 1993) of the Reggio Emilia approach[1], this kindergarten used a developmentally sound curriculum in order to increase the ability of five-year-old children to explore, make choices, accept challenges, become aware of themselves and others, work through problems, and make sense of the many new symbols in their world. The curriculum structure attracted me: children come to school to play as they believe in the concept of play-based learning[2].

The children's class was designed with various play stations, each organised with activities such as block building, craft making, sand and water play, drawing, cooking and baking, etc. provided by the teacher before the child arrived at the school. Some play stations remained unchanged and some were changed throughout the school term. Children had the autonomy to choose which play station they wanted to experience, and this could change at any time. Also, teachers supported children by using a language experience approach to reading and writing, in which stories and books were an important part of each day.

One of the play stations that attracted my attention was 'bird watching' by the classroom window. This activity was introduced during the spring term as a new activity for the children while I was there. It was available almost every day (depending on the weather conditions) over the spring term; some children spent hours a day at this station, although other children only did the activity once a week. The children were provided with various types of binoculars, bird books, drawing stationery and a logbook at this station. They were instructed to carefully observe birds flying/landing outside the classrooms and record their observations in a shared logbook. They were told that if they saw a bird, they were expected to draw its image and features according to what they saw. Some of them coloured in their drawings.

The children were also expected to name the birds they drew by copying names from bird books, and if they saw the same bird frequently – the American robin (*Turdus migratorius*) is the most common bird in the area – they needed to count how often they saw it and record the dates they found the bird. Finally, they were given the option to share the observation results with their friends if they wished, which most of the children did.

[1]An educational philosophy based on the image of the child, and of human beings, as possessing strong potentials for development and as a subject of rights who learns and grows in the relationships with others.

[2]"Play-based learning is defined as purposeful, co-construction of knowledge with others (peers and teachers) within children's social and cultural worlds" (Nolan & Paatsch, 2018: 42, 43).

In the bird watching activity, there were many learning aspects that the children experienced intellectually, socially and culturally. By watching birds, children were using a science process skill called 'observation'. Children were initially trained to use their visual sense to make observations; once they became skilled in observing, they were taught to use tools (e.g., binoculars) to make observations in a more precise and clear way. In the cognitive aspect, children were using their thinking skills of attributing and relating to identify the characteristics and features of birds.

Children were also developing their comparing and contrasting skills (from the bird books) by identifying similarities and differences based on the birds' characteristics and features. With regards to the numeracy aspect, children were taught to count the number of birds they had observed using numbers and to write dates correctly. In relation to the literacy aspect, although at this stage the children were still unable to read and write well, they learned to copy words (spelling and pronouncing a bird's name) from the bird books. Finally, some of them had good social storytelling abilities and had great confidence to share their observational findings with their friends.

The play station activity described above is one example of many related to integrating learning across subjects within the curriculum. In play-based learning, I believe that as children's play experiences change as they develop, so does their concept development. Apart from early childhood education, research also emphasises the importance of play for children in primary education, and its positive effect on the child's development, as well as social aspects such as motivation, security, search for identity, and trying out different roles (Sandberg & Heden, 2011).

However, I found that the approach was very difficult to implement in my context: the curriculum-controlled and heavily centralised educational system of Malaysia. Most importantly, I learned that the application of inquiry or particularly science process skills to young children's learning is entirely possible within that realm. Studying young children's learning has made me think of the extent of children's abilities in primary school and has influenced my design of inquiry-based teaching.

During the exchange programme, I learned many things: I learned how children learn, how they think, and how they grow. As a primary school teacher, I came to realise that every single child is different, and the role of the teacher in the child's development is not as simple as might be expected. As we know, the social and cognitive development of children is growing all the time and teachers have great influence and responsibility in this area. Ultimately, engaging children in inquiry means teaching them to use scientific process skills (e.g., observing, asking questions, describing, providing explanations) in context.

As a teacher, I understand the importance of smoothly introducing children to inquiry and gradually increasing the cognitive demand as they learn new tools and ideas. It's a delicate balance that requires me to constantly assess the needs and abilities of my children. I recognise that there is a continuum when it comes to inquiry-based learning, with the whole class taking on well-structured investigations at one end and pairs of children designing their own investigations at the other end. By increasing the responsibility of the children in undertaking inquiry, I can help cultivate their interest in science, their capacity to undertake an inquiry on their own, and their understanding of science as a way of knowing.

I find that when children are engaged in inquiry-based learning, they are more likely to be excited about science and are more invested in the learning process. They are able to ask questions and seek answers in a more meaningful way, and they develop a deeper understanding of scientific concepts. As a teacher, it is my responsibility to create a safe and supportive learning environment that encourages exploration and experimentation. I need to be able to guide my children as they navigate the inquiry process, providing them with the necessary support and scaffolding they need to succeed.

My educational influences in the learning of others

In the subsequent actions of my doctoral studies, I designed, implemented and evaluated an inquiry-based science teaching with two classes of year four primary children (all of them about nine to ten years old). For the duration of six to seven months of fieldwork, I completed two cycles of action implementation, which consisted of seven lessons. I underwent a cycle of reflective planning, acting, observing, and reflecting for each lesson, all of which utilised inquiry-based science teaching. Throughout these lessons, my focus was on improving my pedagogical practices in three thematic concerns including i) planning component, ii) questioning techniques, and iii) inquiry assessment.

The participating children experienced improved inquiry-based science teaching as a result of the educational influences in my own learning (see Image 3 as evidence of the educational influence in my own learning). They participated in innovative, validated, research-based lessons that consisted of lots of hands-on and practical inquiry activities. The findings of my doctoral studies show that teaching and learning activities are associated with children's engagement in science. Greater levels of child motivation, enjoyment, and future orientation towards science were found in classrooms where children reported that various measures of interaction, hands-on activities and application in science took place frequently.

Image 4. The children participated in a variety of hands-on science activities that allowed them to engage with scientific concepts and practices in a tangible and meaningful way.

Ultimately, my doctoral studies have shown empirically how the teaching of 'inquiry' can be conducted for primary school science. Since there is has not been much emphasis on how the teaching of inquiry should be conducted in a Malaysian primary school, I have demonstrated how inquiry can, indeed, I would argue, should be conducted in practice by integrating it into the curriculum and syllabus supplied by the Ministry of Education, Malaysia. Another question arises, has my integration relevance or significance for fitting 'inquiry' (especially science process skills) into the primary science curriculum in Malaysia? Nevertheless, my doctoral studies have evaluated new initiatives and developed a pedagogical framework for teaching inquiry that can be used within the broader community of science teachers in Malaysia. In fact, it has provided information about the impact of inquiry teaching on children's engagement presented from the perspective of the (usually) unheard voice, the actual teacher-researcher in the practice.

The piece of my doctoral studies also has enacted social change. It has been an empowering experience and undoubtedly has improved my pedagogical skills as a primary school science teacher in Malaysia, particularly in the teaching of 'inquiry'. My expertise in the pedagogical approach of 'inquiry' has been brought back to Malaysia in order to disseminate knowledge and skills to science and other subject teachers in the country (see Ahmad & Mat Noor, 2023; Kamarudin et al., 2022; Kamarudin & Mat Noor, 2023; Othman et al., 2023; Muhamad Dah & Mat Noor, 2021a; 2021b; 2023; Zainun et al., 2021; Zainun & Mat Noor, 2022, for some of the completed projects I have done with teachers in Malaysia). My research has been a catalyst for transformation, intended not only to alter my personal world but also to effect change in our collective world, laying the groundwork for an enhanced educational experience and a more enlightened future (Glenn et al., 2023). I have also been continuing to disseminate the findings of the study to other teachers in an effort to inculcate a research culture in schools (see Mat Noor et al., 2020 and Mat Noor et al., 2021), because I strongly believe in the potential for an advocated change, closing the gap between research and practice (Mat Noor, 2020). Although, I encountered that change is never easy but always possible.

Conclusions

In this article, I narrated my lived experiences from 'where I was at' to how I changed my perceptions and improved my pedagogical knowledge of inquiry throughout my doctoral studies. I also briefly explained the educational influences of my doctoral studies in the learning of others and in the learning of the social formations (Huxtable & Whitehead, 2021). The story started when I was in school as a trained teacher, navigating how my perception of inquiry-based teaching had been shaped. I explained how expressing my values of 'inquiry' and 'education' in my practice became my passion, which continued into my postgraduate studies.

Apart from being influenced by the literature review and evidence-based research, throughout my doctoral studies, I worked hard to explore pedagogical techniques of inquiry-based teaching by participating in various courses/programmes and engaging with science education-related organisations. By engaging in these activities, I have not only enhanced my pedagogical knowledge, but also altered my perception of teaching. As indicated by Bridges (2003), in the final phase of this journey, I realised that the way I was seeing

teaching and pedagogy was different and that I was becoming more appreciative of my educational values and the role they played in my development as a professional educator.

As a teacher-researcher, I see myself in my mind's eye. I have been able to reflect on, argue, offer rationales for my actions, and gain greater confidence in theorising my own practices. By engaging in argumentation and offering rationales for my decisions and actions, I have developed a greater theoretical understanding of my practices, which has increased my confidence in my abilities as a teacher. This process has helped me to clarify my values, beliefs, and practices as a teacher-researcher, and has enabled me to see myself more clearly in my role. The experiences I have shared made me realise that every teacher has the potential to become more effective as long as there is a commitment to learn about one's own practices and to do whatever is required to change teaching practices to enhance children's learning. While each school is unique, the fundamental issues are constant, as all primary science teachers in Malaysia encounter many of the same challenges that I faced.

I believe that science teachers should prioritise inquiry-based methods and age-appropriate, experiential activities when teaching primary science. By doing so, we can ignite a passion for science in our children, encourage their curiosity and critical thinking skills, and ultimately contribute to the development of the next generation of scientists. The conducted study was focused on Bumiputera children in Malaysia, and the intervention applied in this study has the potential to significantly impact the education of this group. Moreover, this study has the power to bring about social change. As a primary school science teacher in Malaysia, I found this experience to be very empowering and it has undoubtedly improved my pedagogical skills, specifically in the teaching of inquiry-based learning. I have now brought my expertise in this pedagogical approach back to Malaysia, where I am sharing my knowledge and skills with science teachers throughout the country. My aim is to disseminate the findings of this study to teachers and in-service teachers, in order to promote a research culture in schools (see Mat Noor et al., 2023a; 2023b). I strongly believe that this will enable us to bridge the gap between research and practice, and advocate for positive changes in our education system.

Throughout my doctoral studies, I learned not to listen to people who told me, "you can't do it". Adopting a Living Educational Theory Research approach to my professional development is about becoming a researcher and that means becoming a theorist and creating and contributing new knowledge. I now realise, too, that real professional development for me has come through researching my own practice and the generation of my living-educational-theory in which I explain my educational influences in my own learning, in the learning of others and the learning of the social formations within which my practice is located. I have begun a holistic transformation of my own practice because I can now see clearly through engaging in Living Educational Theory Research that my values and my practice were at odds. They are now more in harmony as I show in my account of my living-educational-theory, and I feel better, personally and professionally.

Through my doctoral studies, it is without a doubt that my practice as a science teacher has improved. Significantly, I have embraced the role of a teacher-researcher, actively working towards and embodying my values on inquiry and education. These values are not only integral to my identity, but they also critically form the bedrock of my professional practice. What has been particularly affirming is the recognition from others,

who have noticed my commitment to these values and have consequently come to trust my sincerity. A transformative realisation for me has been the importance of taking risks. Indeed, my growing confidence in my ability to embrace risk has opened up new avenues for growth and development, both for myself and others - a journey of discovery I am committed to continuing.

I have developed, and I am now more able to articulate, a better understanding of the teaching with values of inquiry and education, which has a huge impact on my practice as a science teacher in primary schools in Malaysia. My practice as a teacher-researcher will continue to develop, grow and improve as I continue to reflect on, question and evaluate what I do as I constantly seek to live my values in my practice.

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