Peertechz

Annals of Mathematics and Physics
MATHEMATICS AND PHYSICS GROUP
Annals of Mathematics and Physics OPEN ACCESS JOURNAL
mathematics@peertechz.us
ISSN: 2689-7636 DOI: https://dx.doi.org/10.17352/amp

Review Article

Children explore to understand the physical world *Research and practice in Early Childhood Education*

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Received: 18 March, 2022
Accepted: 10 May, 2022
Published: 12 May, 2022

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Keywords: Science in early childhood, Children learning science, Science teacher development, Science teaching in early childhood education

Abstract

All children are inquisitive and begin to make sense of the physical and natural world around them from the time they are born. Children use their senses to explore the surrounding environment. Early Childhood Centres (ECE) in New Zealand provide care and learning opportunities for children under the age of 5-years. Te Whāriki, our mandated curriculum guides teachers. In an exploratory case study, we investigated the science learning experiences provided by an ECE teacher and the children's learning that ensued. The data were collected through case study teacher interviews, mentor notes, and 160 learning stories written by the teacher during the research over two years. We found that a teacher with little background in science was able to provide rich science learning experiences for the children. The teacher's willingness to provide everyday science exploration opportunities and ask questions helped children to develop basic physics concepts. Current research suggests that science is often not taught due to the lack of teacher confidence to teach science because they are generalists and believe they do not have the requisite knowledge or training. Our findings have implications for science teaching and learning in early childhood and primary schools.

Introduction

Human babies are born with only one tool to communicate, crying. Everything an adult human can do is learned from interactions with the environment and from those who were responsible for their care and development. If we look at the history of the development of science concepts, they began with an observation followed by thinking and reasoning [1]. Whether we are talking about Newton and the apple or James Watt and the boiling pot of water. In this article, we propose that early childhood educators can teach science ideas to children even if they *think* they do not know any science. We report the findings of a qualitative research project where an ECE teacher provided opportunities for the children to explore. Evidence of the children's learning and the teacher's development for teaching science is provided as an analysis of *learning stories* written by the teacher for two years and interviews with the teacher twice a year by the mentor. Timely clarification of a science idea was found to be helpful to the teacher.

Learning stories

The Early Childhood Education (ECE) curriculum in New Zealand, *Te Whāriki*, is considered to have a world-leading approach to preschool children's education [2]. First written in 1993, it has recently been revised [3]. Learning is recognized as "responsive and reciprocal relationships with people, places, and things" [4]. Learning stories are written by the ECE teacher and are an effective means of assessment of children's learning. In our practice, we have found these learning stories as a useful reflective tool for the teacher who looks at the story, analyses what has been learned, and decides what is the next step in their planning. Learning stories reported in this article have been a useful point in the discussion between the teacher and the mentor, thus enabling teacher development.

Science Education in Early Childhood

Science teaching and learning is about introducing children to the ways scientists think about and investigate their surrounding environment. Scientists do this in two ways.

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1. They explore and confirm ideas about the environment we live in through investigation and exploration.

2. They form hypotheses or "working theories" to make sense of the environment and identify these as scientific knowledge [3].

Science education in early childhood needs to not only focus on science phenomena but lift its sights to teach what science is and how scientific knowledge is created. Recent research by Hansson, Leden, and Thulin (2021) argued that science education in ECE ought to prioritize teaching about the Nature of Science (NOS). This agrees with the *New Zealand Curriculum* [3] for compulsory years of education up to the age of 18. The school curriculum gives primacy to NOS and places it as an overarching strand, above the contextual strands of physical, material, and living worlds and planet Earth and beyond. Our considered view is that learning about the nature of science ought to begin in early childhood.

Young children are curious and when they are asked to do something, for example, wash their hands, or another request, their most common question is Why? Teachers can create learning environments where teachers can explain *why the request is to be acted upon.* Children know why is an important word and use it very often. By providing interesting activities the teacher can entice them to explore and help them to take a closer look. For example, getting them to gently hit a drum, then hit it harder and asking when the sound is louder and why? This is a useful approach for getting children to come up with working theories during their exploration of the natural world. This is a goal of the Early childhood curriculum *Te Whāriki* [3]. The curriculum has five strands that together focus on the holistic development of children in their early years. These are:

- Wellbeing
- Belonging
- Communication
- Contribution
- Exploration

Central to this research is the Exploration strand. Table 1 sets out the goals and intended learning outcomes of the exploration strand.

Teacher confidence and knowledge

Poor teacher content knowledge has been attributed to students having few experiences of science in early life, particularly in primary schools [5]. What knowledge teachers draw upon has been well researched as Shulman [6] proposed pedagogical content knowledge [PCK] which he defined as "that special amalgam of content and pedagogy that is uniquely the province of teachers, their special form of professional understanding" (p. 8). This refers to the teaching approaches teachers know would be the most appropriate for what they are going to teach. For example, using practical work to illustrate a phenomenon such as potential energy change to kinetic energy.

Table 1:The Exploration strand of Te Whāriki.

Goals	Intended Learning Outcomes
Children experience an environment where:	Over time and with guidance and encouragement, children become increasingly capable of:
» Their play is valued as meaningful learning and the importance of spontaneous play is recognized	» Playing, imagining, inventing, and experimenting
»They learn strategies for active exploration, thinking, and reasoning	»Using a range of strategies for reasoning and problem solving
» They develop working theories for making sense of the natural, social, physical, and material worlds	» Making sense of their worlds by generating and refining working theories

Teacher beliefs are a related area identified as having a strong influence on teachers' classroom practice [5,7,8]. Anderson [5]reported that teacher beliefs about the purpose of science have a strong influence on the teachers' observed practices. She also found that teacher beliefs influenced the subject matter knowledge (SMK) and PCK primary school teachers developed. We wondered if this was the same for ECE teachers. Research in New Zealand primary and secondary schools has shown that when teachers are explicit in modeling, identifying, and describing scientific behaviors, students begin to adopt them for themselves and associate them with science [9].

This led us to investigate in the research reported here the overall research question and related three sub-questions.

What learning experiences can an ECE teacher provide that help children develop basic science ideas?

Sub-questions:

1. *How can a teacher develop science knowledge as they explore alongside children?*

2. *What role does a supportive mentor have in developing teacher practice?*

3. *What did the children learn from the exploration opportunities provided?*

Methodology

This qualitative research was conducted in an ECE center in a large town in New Zealand. The center provided care and learning for between 20 and 25 children under the age of five. The teacher conducted the science learning activities with the children and documented her planning, presentation, and evidence of children's learning through regular writing and sharing the learning stories with the children's families through a digital platform accessed by parents who could read these and write comments if they wanted to do so.

The stories that we have selected are from a collection of just over 160 stories written by the teacher during this research project. The learning stories were written by the participating teacher focussing on the child's physical, social, emotional, and cognitive development as well as the development of

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their literacy, numeracy, and communication skills. Over time, the teacher gained confidence and increasingly provided opportunities for the children to explore observe, think, and share their developing theories about how things work.

The qualitative interview data are typically analyzed through an inductive approach which is aimed to identify categories [10]. The purpose of our research was to determine the complexity of science activities over time and make sense of the teacher's role in children's learning. The conventional inductive approach to qualitative data analysis was not fit for the purpose. [11,12] proposed the notion of deductive qualitative analysis. According to Gilgun [12], a deductive qualitative analysis begins with a conceptual model that is used as a screen placed over the data to 'compare the patterns of the conceptual model with the patterns of the findings '. We analyzed the data using the research-informed curriculum framework. Using the *Te Whāriki* framework, over time and with guidance and encouragement, children become increasingly capable:

- Playing, imagining, inventing, and experimenting
- Using a range of strategies for reasoning and problem solving
- Making sense of their worlds by generating and refining working theories

(Ministry of Education)

Analysis of a learning story

First, the 160 learning stories written during this time were read and reread to identify the focus of each story. This was needed because learning in most stories was multifarious and could be linked to several strands. An example of this is presented in Figure 1. The complete framework can be accessed from https://tewhariki.tki.org.nz/en/teaching-strategies-and-resources/exploration/

This learning conversation shows that the initial exploration got Martin interested in the snail. He wanted to learn more and share his learning. It shows that his interest continued beyond the exploration, and he found and brought along a snail to the center, which led to further learning. Martin used his reasoning when he returned the snail to the letterbox where he got it from and explained later why the snail was not in the letterbox. Exploration provides a learning opportunity for all the children. For some children, it gets them interested in wanting to learn more. It also helps children to be thoughtful of the little animals and learn to care for them. Martin has been investigating snails and using reasoning to offer explanations. This story provides evidence of cognitive and social development and focuses on the exploration strand. However, it also shows teachers' and child's contributions to learning. Above all these show, Martin's excellent communication skills, social skills, and ability to hold an adult conversation.

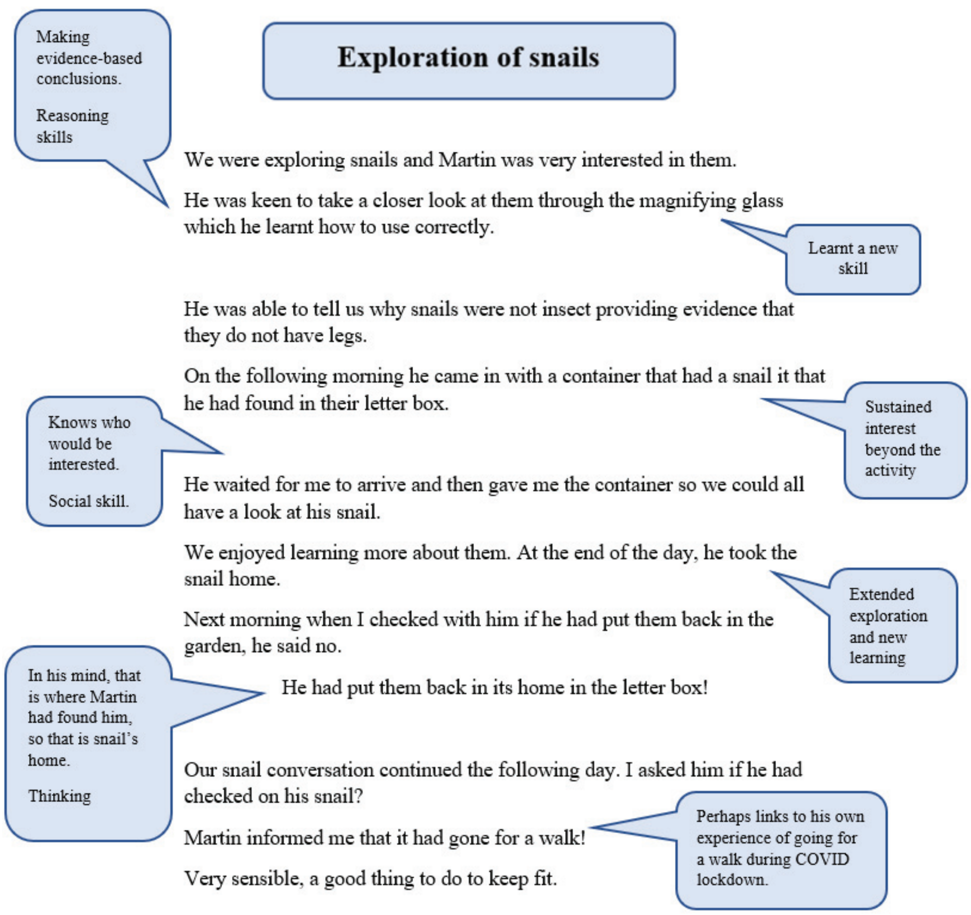

Figure 1: Example analysis of one learning story

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Analysis of learning stories related to each stand of the curriculum

The ECE teachers are required to document children's learning. These stories cover many different aspects of the curriculum. Our focus being exploration, we wanted to select stories that focused on exploration and provided insights into children's science learning. We read the 160 stories and used the curriculum strands as a guide for grouping them as shown in Table 2.

What children learned from the exploration

We selected four learning stories to share as evidence of learning, not because they were the best stories but because they demonstrated the development of children's understanding of Physics ideas. These are presented below as vignettes and are followed by an analysis.

Exploration of three balloons filled with air, water, and ice

Vignette 1

Children were given an air-filled balloon, a water-filled balloon, and a frozen balloon to feel and compare. Dan reported that the air balloon was light, and the water balloon was heavy. They all felt the water balloon and said that it felt squashy. As the balloon was passed along Danny squashed it a bit harder and the water balloon popped. Through being able to squash them children managed to pop more balloons and had fun doing so. Eva and Eli had helped me to fill balloons with water on the previous day, so we went and got those from the freezer. Everyone agreed that they felt cold. Then the balloon slipped off and they had ice in their hands.

When asked how we can make the ice melt faster? Tama said by taking it outside. There the sun would help to melt it faster. Great ideas, but it is a very cold and cloudy day so we will try that on a sunny day. They were asked, what could we do inside? We can put it in warm water Noah suggested. Great idea Noah, we got a bowl of warm water and put one balloon in it, and had another one on the table to compare. There was much excitement and children observed the ice balloon gradually melting.

Sana remembered that earlier we had put salt on ice to make it melt faster. So, we got the salt and the children sprinkled it on the ice. After a while, children felt the surface and declared that it was scratchy now, not smooth any longer. Sally added that it was getting smaller too. Sam who was observing the balloon placed in the empty bowl, said he could see water around it. When asked where the water came from, he confidently offered his theory that the ice had melted.

Table 2: Analysis of learning stories according to Te Whāriki strands.

Strand	Numbers of stories with focus strand
Wellbeing	31
Belonging	13
Communication	46
Contribution	22
Exploration	48

Eve suggested that if we put a balloon filled with water in the fridge it would freeze and was immediately corrected by Sam, who said 'freezer not fridge'.

Children continued to play with the water and ice for a long time.

As apparent, this activity was planned to give children the opportunity to learn about light, heavy, soft, and hard. At the end of the activity, these three- and four-year-old children were able to explain how ice can be made to melt faster and how water can be frozen to make ice. The story also shows that these children are learning to play together which helps to develop their social skills. Through questioning, children were encouraged to communicate, and, in the process, new words were learned by all.

Floating and sinking

Vignette 2

As the children were so keen to play with ice, the next activity also involved balloons.

We did this activity in our water trough. Children took turns placing an air-filled balloon in the water. They tried to push it down and it just kept coming up. Anna declared; that this balloon is light it will not drown!

They were asked to predict what would happen if they put the water-filled balloon in the water. Tim offered it will drown! When asked why he thought that he said because it was heavy. When he put it in, it did not drown! They were introduced to the words, float, and sink. They were all certain that the ice balloon would drown/sink. But it did not sink. Some children tilted their heads and looked sideways and added maybe it is going to sink. Jane added a bit is floating and some are not. Noah had the last word, he said that this is like an iceberg.

As the children had enjoyed the activity so much, on the following day they were given many objects to sort out into those that float and those that sink. We started the activity with children predicting, explaining, observing, and expanding. At the end of the activity, children looked at things that float and concluded they were all made of plastic and were light. Metal and rock and other heavy things sank. Mira found that the hard rock sank and volcanic rock which is pumice floats. She also found pumice is lighter than hard rock. We talked about how pumice forms.

Sebastian found a stone and each time he put it in, it sank. When asked how they could make the stone float Seb became excited to show how it worked. He put the stone in a plastic lid, but he was in a rush to do this, and it sank. But he tried again and put the stone on the lid, and it floated. Seb continued exploring. He put a metal bowl in the water, and it floated. He put other things that were sinking into the bowl and made them float and had fun making the sinkers float.

When asked, why things did not sink, he said, 'It is like a bowl' and moved on to play outside.

This learning story shows that children are engaged in hands-on exploration. The teacher provided the opportunity for children to *compare*, which requires higher-order thinking.

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The children were able to make comparisons. The teacher invited children to offer their theories about floating and sinking. Through questioning, she got children to predict what might happen and why that might happen, for them to experiment, make observations, and offer explanations. This strategy is called Predict Explain Observe Explain (PEOE) [13]. PEOE helps have *minds-on* engagement in a *hands-on* activity.

This story also shows that the teacher can reflect on a planned activity and then think of ways to extend it. Her concern was that this group had several new children who had not experienced the previous exploration. However, they were playing alongside other children like Seb and observing his experimenting. Seb had a conclusion to offer from his experimentation.

Problem-solving and identifying patterns

Vignette 3

I had been watching Dan playing with the cars in the block area alongside other friends. He made a long road with the road tracks and used the long blocks to make the side walls. He was also using the arch-shaped blocks to make a tunnel. He found that the long block does not fit the tracks where the track bends. Dan moved the long blocks and placed a small rectangular block that covered the inside and then he used a small square block to fill the gap on the outside of the bend. Dan wanted to complete the track with no gaps. It was nice to see the way Dan solved the problem. Well done, Dan, excellent problem solving, and you are good at recognizing patterns.

Close observation of children's play is an important aspect of ECE. When the teacher stops and looks at children busy doing an activity of their choice, they find out the child's interest as well as their learning behaviors. This is an important step in planning future learning activities.

Children explore the properties of magnets

Vignette 4

Children love playing with magnetic shapes. They often make patterns and build the structure using them. They already know that magnetic shapes stick to each other, and I have noticed that children find the shapes repel while they try to connect them.

Following their interest, I thought to bring some magnetic toys for them to explore the magnetic properties. The box contains toy cars with built-in magnets, a couple of toy people also with magnets, some magnetic discs, sticks, and a sealed container that has some iron sand.

When I set up the toys, children came along and sat on chairs. Magnus and Adrian chose the cars, and I distributed the people and magnetic sand to the other children. When they finished playing with their toys, they were asked to swap their toys with others. Mary was happily exploring the magnetic people and how they could bounce when she put the magnetic disc in.

Adrian tried to stick to yellow sides of the circle to the yellow sides of the bar magnet, and he worked out that the purple and yellow sides stick together. Mary and Sam found that two yellow sides of the disk pushed each other away (repelled) but different colors stuck together. I heard Harry notice that the disc magnets are donut-shaped. Cam and Tom noticed other children playing and patiently waited for their turn.

Cam moved the car backward and forward without touching the car. While exploring the magnetic toys children had a lot of fun. They worked out that when two magnets were brought close to each other, they either pulled together or pushed each other away. They also worked out that they could move the toy cars backward and forward without touching them. Tom said, "magnets do not have to touch to make things move".

This learning story shows how children link new ideas to their existing ideas to construct their understandings of a phenomenon. They have played with magnetic strips and figured out that they sometimes come together and at other times push away. The magnetic toy provided several different ways of reinforcing the learning and finally, at least one explorer figured out that magnets do not have to touch the object to move it, while others observed. These thoughts are the beginnings of the understanding that magnetic force can also work from a distance.

Teacher development

Seema (Pseudonym) the ECE teacher's science teaching journey began with fear of not having knowledge and a strong belief that she could not teach something she did not know as is evident in the following comment she made in the first teacher interview.

"I don't know science" how can I teach science to little children?

At this point, it was important to first draw her attention to science in her everyday life which she did not view as science. The mentor was supportive and offered the following suggestion.

Not having a background in science Seema does not think she knows much about science. I suggested that children could learn about fruits, that is science. They could use their senses to see, feel, smell, and taste. Seema thought this was a good idea and she could ask questions to encourage the children to explore and talk about the fruit. She decided on apples, and I think this was because most children would be familiar with this fruit. (Mentor notes).

Seema bought red and green apples for her first science activity. This was something she knew about and could see herself talking with children so that they would learn something about the different qualities of a fruit. With some apprehension and excitement, she thought that would be doing a *science* activity. Thus began her development as a science teacher of little children. The following is an excerpt from her first learning story.

We decided to focus on one fruit each week. Today's fruit was an apple. The children all looked at the apple and said it was round, red, and green. When we cut it up and they tasted

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it, Samara said it was sweet and Tim said it is crunchy. Children enjoyed eating it. We talked that it can be different colors, red or green. Apples are also juicy. Leah said she likes apple juice.

Having crossed the first bridge, Seema was reluctant but sent her story to the mentor, who appreciated and encouraged her to continue the effort. Towards the end of the first year, Seema wrote the following story.

Yummy pear, our food of the week!

When possible, we choose seasonal fruit and this week pear was our food of this week. Susan, Mili, Sara, Tom, Nathan, and Rangi sat around the table. First, we talked about pears, and then the children took the opportunity to take a closer look, feel them, describe their shape, and talk about how their skin felt. Susan said it is not round. Tom added it is round, but it has a long bit on top. After some thinking, Tom said that the shape of the pear was like a spaceship, while Sara described it as a circle. Mili described it as a triangle and Nathan said its shape was like a giant belly button. Rangi waited his turn and got the shape sorted for us, he said it is pear-shaped! Indeed, what better way to describe a pear? We talked about a new shape that we had not learned yet. The pear was like a cone.

Next, we cut the fruit in half, looked at the inside, and saw the seeds. Then we all ate a piece of pear and the children talked about the fruit is juicy, and how it smelt and tasted. Then they drew pictures of the fruit.

The above excerpt from a learning story provides evidence of Seema's development as a teacher. The stories started to have more detail. She has taught children about different shapes. The fruit activity has become part of her teaching routine. Children were being encouraged to use many senses to explore. She is acknowledging the children's responses. At the same time, she began to write a reflection after each activity. The activities became increasingly complex as was evident in the vignettes presented earlier in the paper.

The following excerpt is from our last interview: I have planned several science activities so that the children have a wide range of experiences. These have included short-term activities such as making close observations of snails or flowers, visiting Te Papa, and following up the learning's on this trip by sorting different types of leaves or different types of animals. Looking at similarities and differences between them. The fruit of the week activity has also allowed time for science learning. Children enjoy water play which is great for teaching about floating and sinking. They loved the story of Who sank the boat. Last week the children did a ten-pin balling activity. We had lots of different balls. I asked them to choose one they thought would knock over most pins. They predicted and then experimented (Figure 2).

Through these activities, I have been able to focus on conceptual development, which is a requirement of our early childhood curriculum *Te Whāriki.* One aspect that has worked particularly well is doing a formative assessment with children who were continuously interested in doing science activities so I can focus my planning on their particular learning needs.

As Seema gained confidence, she needed less and less help from the mentor. From the analysis of the learning stories, her interviews at the start and the end of both years, her written reflections, and mentor notes, her development can be seen in the following figure.

Discussion and Conclusion

Evidence suggests that the children experienced regular engagement in science activities. They learned to explore and come up with their working theories, and through questioning were required to refine these, which meet the requirements of the curriculum [3]. Children had the opportunity to play, imagine, experiment, and solve problems under the intention of the exploration strand [3]. Children developed science vocabulary and were able to understand that water can be frozen to make ice and ice can melt to become water. They knew how ice can be made to melt faster. At this age, understanding the phenomenon of change of state from liquid to solid and verse versa we believe is adequate. They do not need to know that this *is* called a change of state. Similarly, children were not only able to conclude that magnets can attract and repel. Some things are attracted to magnets and others are not. The children could work out that magnets do not need to touch the object to make it move. That magnetic force is not a contact force is something that can come later. We believe that children were developing conceptual understandings of science ideas [14]. By Abrahams [15] and Hodson [16], these activities encouraged hands-on engagement and the questioning that followed needed minds-on thinking and reasoning and offering evidence-based explanations. These children were doing science, and talking science, reading science, writing science, and understanding representations can be appressed in primary science education [17]. In practice, they are beginning to have a practical understanding of the NOS that scientists make observations, ask questions, experiment, solve problems, and make evidence-based conclusions. Scientific practices are becoming embedded in their learning.

This research showed that a generalist teacher who has little content knowledge and lacks confidence can indeed provide opportunities for little children to explore and make sense of the physical and natural world. To think and accept that ECE or primary school teachers are generalists and therefore know no science needs fresh thinking. Are we not valuing their education up to the age of 14 years when without a doubt most students learn science? They may well have forgotten it as they learned other subjects things, but they knew it once and if they have trained to be teachers, they have demonstrated a capacity to learn and relearn. We need to build ECE teachers' confidence by reminding them that what they will need to teach at this level is no more than what they had learned earlier in their schooling. If teacher education provides what Bull [18] calls *a library of experiences* and helps build up their tool kits then they will not be fearful of teaching science. They may well enjoy learning alongside their children as this teacher Seema has.

Mentoring required minimal but timely input from a more experienced science teacher to give an idea and let the teacher try it out. In the present digital age, knowledge is accessible

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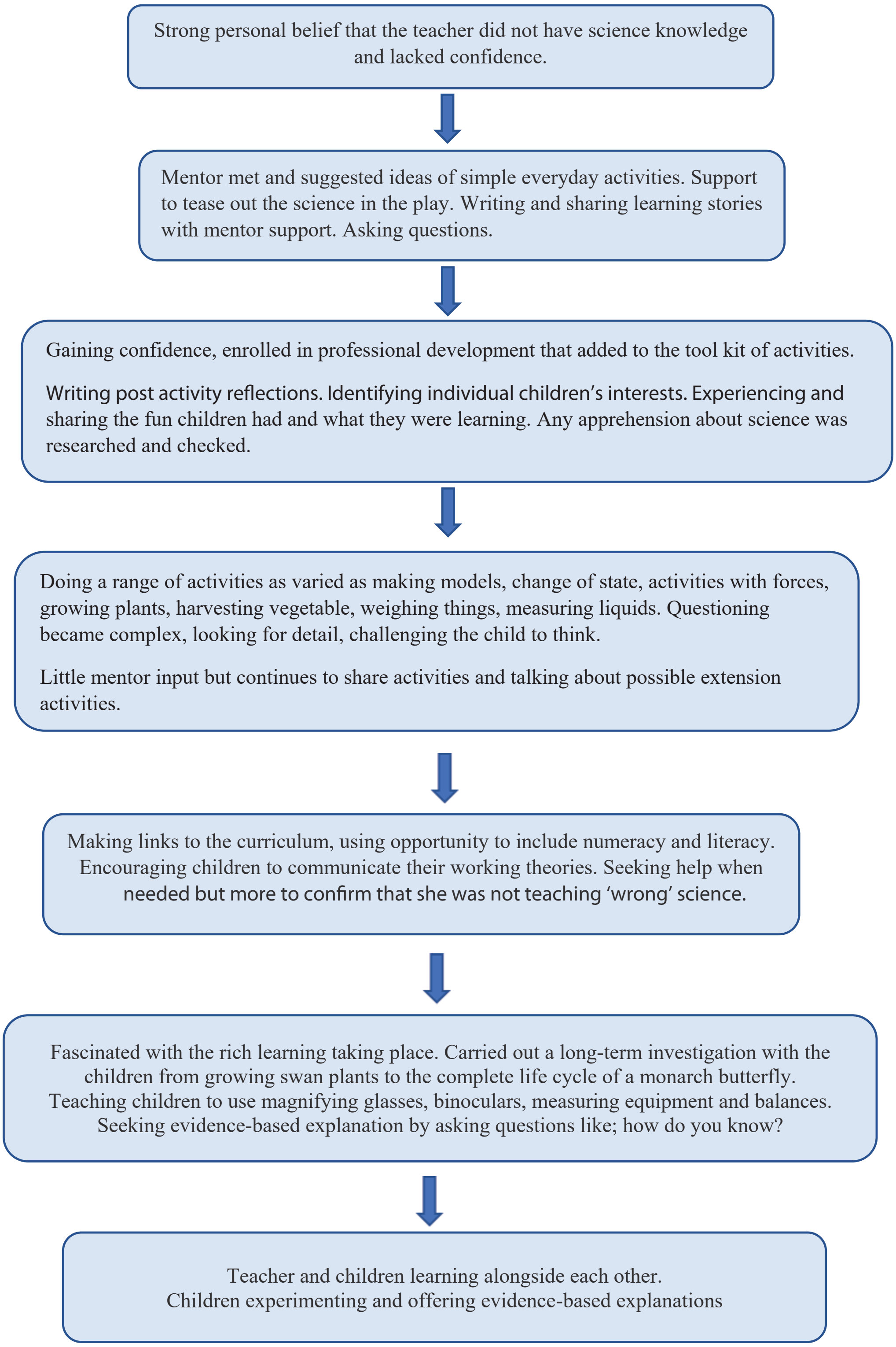

Figure 2: Teacher development from a novice to a confident teacher of science in ECE.

to all teachers so perhaps, access to a science advisor who can encourage and share science activity ideas would be enough. The task is not insurmountable, we just need to do it.

NOTE: Ethics approval was granted by Victoria University Human Ethics Committee. All effort has been made not to identify the children, the ECE Centre, and the teachers .

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