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To what extent do primary school children understand photosynthesis?: a study of children's drawings with follow-up interviews

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ABSTRACT

This study aimed to investigate primary school children's understanding of photosynthesis. We employed children's drawings as an instrument and conducted one-to-one follow-up interviews with 48 children of primary school age (7–13 years old) in a national primary school, in a suburban area of Melaka, Malaysia. The findings of the study indicate that as children progressed through primary school, their understanding of the concept of photosynthesis improved. The study sheds light on the varying levels of conceptual understanding of photosynthesis among primary school children and how this can inform the teaching strategies of science teachers to facilitate children's understanding of this concept. In addition, this study makes a valuable contribution to research on biology education by demonstrating that using drawings as a research instrument alone is insufficient to fully capture young children's conceptual understanding.

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Children's drawings; children's understanding; photosynthesis; plant growth; primary school

Introduction

The foundations of biology education can be traced back to the early stages of schooling, encompassing preschool and primary education. Embedded in the science lesson, it aims to cultivate children's inquisitiveness and promote creativity by means of immersive daily encounters and exploratory investigation (Mat Noor 2022). These early stages serve as a crucial precursor to the development of students' advanced concepts and skills during their secondary school years (Tunnicliffe and Ueckert 2011). It is paramount to note that the primary school curriculum's role in biology education extends beyond imparting knowledge; it also holds the key to igniting and sustaining children's interest in biology, as research suggests a decline in motivation with age (Bulić and Blažević 2020; Prokop, Prokop, and Tunnicliffe 2007). Consequently, there is a compelling need to explore children's conceptions of biology topics in these formative years to inform effective teaching strategies, address misconceptions, and foster a deep and lasting appreciation of the subject.

Harlen (2010) emphasised the systematic cultivation of curiosity, fostering of delight in scientific exploration, and promotion of understanding concerning natural phenomena in primary science education. In biology, the foundational concepts related to life and the criteria defining living entities – concepts frequently encountered by young learners – assume a pivotal role in nurturing their active engagement and curiosity (Stepans 1985). Despite the inherent complexity of abstract

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biological ideas, primary school children can grasp concrete biological knowledge through pedagogical approaches that encourage practical, thoughtful participation and hands-on experiences (Carlan, Sepel, and Loreto 2014). This underscores the critical significance of introducing biology to children in the primary school setting, as they possess untapped learning potential that transcends conventional assumptions, and the teaching approach should revolve around presenting biology as an intuitive narrative (Fail 2007).

Curriculum on plants in primary school

The early primary school biology curriculum covers the topic of humans, animals and plants. Plants appear to receive less emphasis in the science curriculum and biology textbooks with regards to these three issues as compared to animals (Schussler et al. 2010). As a result, children may have a greater interest in animals than plants and tend to overlook and dismiss the latter as living things (Patrick and Tunnicliffe 2011). Children may have plant blindness, a common situation where people ignore the plants around them when examining the natural world (Comeau et al. 2019). The case of plant blindness, even in relation to the essential topic of plant structures, affects children's view and understanding of plants and their life processes, thus contributing to their misconception about plants. The plant curriculum therefore gives an insight into children's conception of plants.

Based on Table 1, around the world, the primary school curriculum on plants differs according to geographical region, as demonstrated in examples from countries such as the United States (National Research Council 2013), United Kingdom (Department for Education United Kingdom 2013), Singapore (Ministry of Education Singapore 2014) and Malaysia (Ministry of Education Malaysia [MOE] 2018). In general, at the beginning of primary schooling, children learn basic concepts like the structure and growth of plants. The most complex plant-related topic that they know about is the support and transport system needed by plants. However, most countries do not introduce the topic of photosynthesis in primary school, and thus, students began to study the topic in their secondary schooling years. This omission raises questions about the foundational understanding of young learners (Lee and Yeo 2015). However, photosynthesis is introduced for 10-year-old children in Year 4 of primary school in Malaysia, where this study was conducted. By the end of the topic, children are expected to be able to: (1) state the meaning of photosynthesis, (2) list the needs of plants for the process of photosynthesis, (3) state the products of photosynthesis through observations using various media, and (4) provide reasoning on the importance of photosynthesis for living things (Ministry of Education Malaysia [MOE] 2018). The curriculum outlines the key components of teaching photosynthesis to children, including definitions, necessary elements and the significance of the process within ecosystems (Kamarudin, Mat Noor, and Omar 2024).

The above approach is timely as it aligns with the growing emphasis on teaching scientific practices to promote conceptual understanding within primary school settings (Muhamad Dah et al. 2024). A part of this initiative, there is a renewed interest in understanding the cognitive pathways children take towards mastering core scientific concepts and skills and developing relevant theoretical models, as outlined by the concept of learning progressions (Osborne et al. 2016). With regards to the learning progression on the topic of plants, Allen (2016) asserted that teachers should organise their lessons to match the way children naturally learn about scientific concepts. Although these concepts are not strictly linked to specific age groups, they might be more commonly associated with certain ones. The learning progression on the topic of plants starts with plant classification, growth requirements, plant nutrition, and plant reproduction, with various subtopics expanding as children grow (Allen 2016). This highlights the importance of including photosynthesis, which falls under plant nutrition, in the primary curriculum, as children need to understand that plants make their own food and consume it, the very same as other living things (Allen 2016).

Table 1. Plants curriculum in primary schools in the United States, United Kingdom, Singapore and Malaysia.

Grade	United States	United Kingdom	Singapore	Malaysia
Grade 1 (6–8 years old)	- Plants use their external parts to help them survive, grow, and meet their needs - Young plants are like, but not exactly like, their parents	- Variety of common wild and garden plants - Basic structure of a variety of common flowering plants	No science subject for grade 1	- Parts of plants
Grade 2 (7–9 years old)	- Plants need sunlight and water to grow - Diversity of life in different habitats	- Plants' habitat - Seeds' growth - Basic needs of seeds	No science subject for grade 2	- Plants' growth
Grade 3 (8–10 years old)	- Plant life cycles - Plants have traits inherited from parents - Environmental changes and the types of plants that live there may change	- Parts of flowering plants - Requirements of plants for life and growth - Water transportation in plants - Part that flowers play in the life cycle of flowering plants	- Plants as living things - Plants' life cycle - Sexual reproduction of flowering plants - Parts of plants and their function	- Reproduction of plants
Grade 4 (9–11 years old)	- Plants have internal and external structures that function to support survival, growth, behaviour, and reproduction			- Plants respond to stimuli - Photosynthesis
Grade 5 (10–12 years old)	- Plants get the materials they need for growth chiefly from air and water - Movement of matter among plants, animals, decomposers, and the environment	- Reproduction in plants	- Plant support system and its function - Water transportation in plants - Plant cells - Plant adaptation	- Survival of plant species - Dispersal of seeds
Grade 6 (11–13 years old)	Grade 6 in middle school	- Classifying plants based on specific characteristics		- Interaction among plants - Preservation and conservation of plants

Children's conceptions of plants

Previous studies on children's conceptions of plants can be discussed in relation to their specific cross-age or non-specific cross-age focus. Most of the research covered cross-age studies. These studies highlighted that a series of observable changes occurred, from children's conceptions in early childhood to their conceptions at the end of primary schooling (Amprazis, Papadopoulou, and Malandrakis 2021; Anderson, Ellis, and Jones 2014; Rybska, Tunnicliffe, and Sajkowska 2017; Tunnicliffe 2001; Villanueva, Villarroel, and Antón 2021). Amprazis, Papadopoulou, and Malandrakis's (2021) study aimed to establish the extent of plant blindness among primary school children and to determine whether this phenomenon was related to children's reported difficulty recognising plants as living creatures. The results indicated that children found animals more interesting than plants and that plants were not spontaneously remembered as living things. As children matured, their interest in plants waned due to intensive biological changes and emotional growth.

In Anderson, Ellis, and Jones's (2014) study, children's drawings were analysed to determine how children conceptualised plants' structures and functions. The study showed that young children were aware of fundamental plant structure and function concepts. However, older children began to create more comprehensive drawings and, in some cases, included secondary objects or materials and other sorts of organisms in their drawings that they believed aided in the growth and survival of plants. Similarly, Rybska, Tunnicliffe, and Sajkowska (2017) conducted a study to ascertain children's comprehension of the internal structure of trees. Some statistically significant disparities between age groups and genders were evidenced when children answered questions about the internal structure of plants. However, certain concepts were understood across age groups, indicating that children may resist change in the knowledge acquired. Additionally, the study uncovered several alternate views on plants' internal structure, indicating changes in children's prior knowledge.

Tunnicliffe (2001) investigated primary school children's verbal remarks when visiting plant exhibits. The study showed that older children had more awareness of plants, thus making them susceptible to commenting on plants with their peers rather than discussing topics unrelated to plants. Furthermore, Villanueva, Villarroel, and Antón (2021) studied drawings of plants created by young children during two different time periods, separated by a year. The study showed that there were significant differences between the two drawings. Younger children's drawings of plants were related to abiotic factors. In comparison, in older children, the drawings were linked to representing other living things like animals.

However, some studies did not discuss the varying conceptions of plants among children of different ages (Comeau et al. 2019; Gatt et al. 2007; Kühnis and Fahrni 2021). For instance, Comeau et al.'s (2019) research was conducted to elucidate plant blindness using third-grade children's drawings. The results showed that regardless of plants' macro-features, the children simplified them, and certain illustrations contained inaccuracies, even though the children were near the indicated plant. These findings suggest that mental models of plants are already established in this age range, possibly resulting in plant blindness. Meanwhile, in Gatt et al.'s (2007) study, young children had limited knowledge of phrases and interpretations related to plants. This was because young children relied on their parents as the main source of knowledge about plants. However, children's knowledge increased with age as they entered formal school and gained information from the learning process.

Kühnis and Fahrni's (2021) pilot study examined the extent to which primary school children were familiar with common local plant species. The study showed that children who grew up in a garden performed substantially better at species identification than children from non-gardening families. Additionally, regular combined nature trips with parents and children of parents who taught them about nature were also connected with increased plant knowledge among children. In general, all of the studies mentioned above cover children's perceptions of plants and their understanding of plants' structures and functions. However, there are still limited studies on primary school children's conception of plant growth and photosynthesis.

One study that highlighted primary children's conceptions of plant growth was that of Simpson and Arnold (1982). The research concluded that primary school children aged 11 had an elementary knowledge of plants and a limited understanding of living things. Their assumptions about where plants get their food were inaccurate. Similarly, in the study of Barman et al. (2006), primary school children could identify several factors that affected the growth of plants. Yet still, they had different interpretations and misconceptions when explaining how the elements contributed to plant growth and how they interrelated with one another. However, the children's explanations about how plants grew improved with age.

In a recent study, Barrutia and Díez (2021) explained children's different forms of understanding across three diverse age ranges in primary school. The study showed that children between the ages of 6 and 8 years old tended to reflect an anthropocentric perspective of plants and mention water or sunlight as the primary elements that plants require for nutrition. Meanwhile, children aged 8–9 indicated a rudimentary understanding of photosynthesis but lacked a whole notion and had severe conceptual flaws. Finally, at the end of the primary schooling years, with particular regards to children aged 10–11 years old, the study showed that with increased instruction in plant nutrition and a more vital ability for abstract thought at these ages, children began to characterise the sun's role in plant nutrition more precisely, claiming that it supplies light or energy to plants.

However, a few gaps were found in previous studies of children's conceptions of how plants grow. All three cross-age studies compared primary children's conceptions with secondary or university students' conceptions. For example, in Barrutia and Díez's (2021) study, the main purpose was to use students' drawings and explanatory texts to assess if there was a progression in the acquisition of plant nutrition knowledge from primary to secondary school (compulsory education), and to compare it to the understanding of elementary pre-service teachers (university level). The sample was selected from three different school levels rather than further probing the conceptions of one specific age group. Based on the study's findings, it is unclear how the children's conception of plant growth was explained as the data were compared with other age groups.

Meanwhile, the instruments used for the data collection indicated that the research was not fully immersed in gaining a more profound understanding of children's conceptions. In Simpson and Arnold (1982), the researchers implemented individual interviews; in Barman et al. (2006), the researchers asked questions based on a set of pictures; and in Barrutia and Díez (2021), a pre-designed paper and pencil test was used that included students' drawings and explanatory texts. Thus, combining different instruments will provide a range of data on children's conceptions to elicit a deeper understanding of children's ideas about plant growth.

Considering the gaps in the literature, the present study attempts to make a notable contribution to biology education research with particular regards to primary school children's understanding of photosynthesis. Previous studies primarily compared children's conceptions across broader age groups, thus providing no clarity on how specific age groups of primary school children comprehend these processes. In addition, the utilisation of drawings as a research instrument alone is insufficient to fully capture young children's conceptual understanding. Hence, this study aims to provide a more comprehensive and nuanced insight into Malaysian primary school children's conceptualisation of photosynthesis by narrowing the focus to this particular age group and utilising multiple data collection methods. This approach is essential to effectively identify potential misconceptions and tailor science education strategies and curriculum development to meet their needs and comprehension levels.

Methodology

The study follows an exploratory research design and methodology, employing children's drawings and one-to-one interviews to understand Malaysian children's conceptions of how plants grow. In social science, exploratory studies come in various forms, depending on what they aim to achieve and how they go about it like looking into existing topics to come up with new ideas or hypotheses (Elman, Gerring, and Mahoney 2020).

The use of children's drawings as a method of data collection has been widely recognised as an effective way to gather information about children's concepts, as drawings are a systematic form of expression common to all children and have been shown to boost science learning (Areljung et al. 2021). Drawings assist young children in transitioning from ordinary to more scientific concepts, making them better equipped to operate at a metacognitive level when they create visual representations of their thoughts (Anderson, Ellis, and Jones 2014). While a study of children's drawings may help gather information about their concepts, the data must be accompanied by an explanation of the significance children assign to their drawings (Ehrlen 2009). Thus, in-depth interviews were conducted to gain additional information on children's drawings, as young children lack command of the written language and can better express themselves verbally (Gatt et al. 2007). Rybska, Tunnicliffe, and Sajkowska (2017) asserted that each child's drawing is an expression of their unique concept and depicts a mental model of the object.

The study was conducted in one national primary school in Malaysia, designated Sekolah Kurang Murid (literally translated as a Fewer Pupils School), where the main author was a science teacher. Sekolah Kurang Murid refers to schools located in suburban areas as opposed to urban areas, which often enrol fewer pupils than their urban counterparts, typically less than 100 pupils in a school. Forty-eight children were selected to be participants, which covered students across all age levels from Year 1 to Year 6. Table 2 provides information on the participants in this study.

Individually, participants were asked to depict their thoughts on how plants grow on a blank A4 sheet of paper. The time allocated for the children to complete the task was up to 30 min using any writing tools owned by the participants. Each child was instructed to label the elements included in their drawing. However, some younger children had problems with writing. In this instance, the researchers aided the children in labelling their drawings and took precautions in writing the exact words uttered by the children. Lastly, all the children were interviewed about their drawings. The interview session, which followed a semi-structured format, was conducted individually, and the participants were asked a series of questions while holding onto their drawings. The participants were expected to answer questions about their drawings and labelling as the circumstances associated with their drawings should ignite curiosity and enthusiasm for a subject asked (Muhamad Dah et al. 2023).

The data collected from children's drawings and in-depth interviews were analysed using reflexive thematic analysis. This approach underscores the researcher's proactive involvement in data coding and analysis, emphasising the need for thoughtful reflection on theme development and recognition of the inherent subjectivity involved, which is influenced by the researcher's perspectives and methodologies (Braun and Clarke 2021). Through a collaborative process, we collectively identified, refined, and deliberated on codes and categories to enrich the intricacy of data interpretation. Drawing upon our shared theoretical underpinnings, analytical expertise, and gleaned insights from the data (Braun and Clarke 2021), we determined emerging themes pertaining to the children's conceptual understanding of photosynthesis. This process not only contributes to the credibility of this study, underscoring the importance of consistency achieved through triangulation and saturation in establishing dependability (Janis 2022), but also addresses the role of reflexivity in maintaining trustworthiness, particularly in terms of transparency and self-awareness (LaBanca 2011).

Table 2. Participating children involved in the study.

Year	Age	Number of children
1	7–8	7
2	8–9	8
3	9–10	6
4	10–11	8
5	11–12	9
6	12–13	10

Table 3. Rubric for children's conceptual understanding of photosynthesis.

Level	Conceptual understanding	Description
0		Scribble/indecipherable
1	Pre-elementary	Only some of the basic needs of plants were mentioned (e.g. water or nutrients) for the optimum growth and development, with no specification on how the plants obtained them.
2	Elementary	Children suggested how the plants obtained the elements for growth (e.g. soil or air)
3	Basic	Children mentioned all the basic needs of plants, indicated where the plants get these elements from (e.g. soil or air) and through which parts of plants (e.g. leaves or roots).
4	Partial	Children provide the initial conception of photosynthesis (e.g. needs or products of photosynthesis) but did not describe the process of photosynthesis at the specific parts of plants.
5	Advanced	Children indicated all the needs and products of photosynthesis and thoroughly described the process of photosynthesis that occur at the specific parts of plants.

Drawing on the analysed data, we adapted a rubric based on previous studies on children's conceptual understanding of plant nutrition (Barrutia and Díez 2021). The rubric can be seen in Table 3. Furthermore, during the interview analysis phase, specific excerpts from the interviews, meticulously chosen for their relevance and representativeness, were utilised to guide the data analysis process. This selection process was conducted using psychoanalytic approaches, focusing on instances of disruption during the interviews – such as sudden pauses in one participant's conversation and immediate concurrences and interjections from another participant – to explore their potential significance for the participants' and researcher's reflexivity (Holmes 2013). These moments were recorded to aid an understanding of the children's drawings and the underlying symbolism, facilitating the construction of narratives that might otherwise have remained obscured (Eldén 2013). These selected excerpts demonstrated children's conceptions regarding how plants grow and the photosynthesis process, thus facilitating a more in-depth examination of their understanding, identifying common themes and misconceptions, and contributing to a richer and more nuanced interpretation of the findings.

Results

To examine children's understanding of photosynthesis, their drawings and interviews were analysed individually according to the conceptual understanding levels defined in Table 3, which served to categorise children's responses about plant nutrition. The drawings and interviews were analysed in terms of the elements plants need for optimum growth and development, where plants get these elements from, the plant organs involved, and the process of photosynthesis.

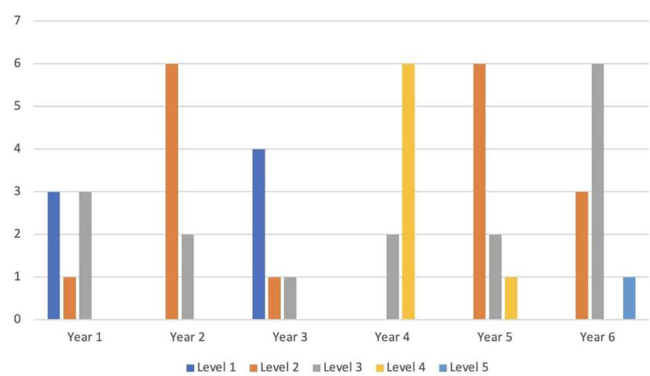

Figure 1. Children's conceptual understanding inferred from drawings.

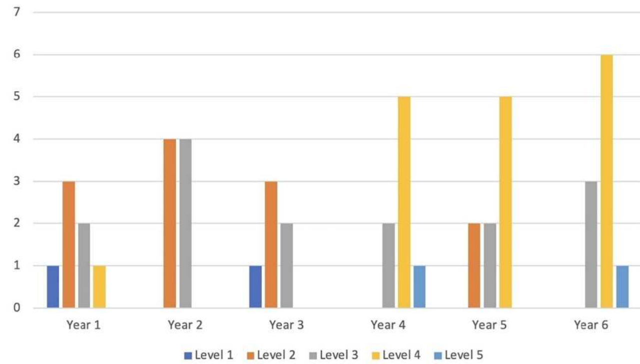

Figure 2. Children's conceptual understanding inferred from interviews based on their drawings.

The most prevalent trends in children's conceptual understanding at each level of schooling, as inferred from the drawings and interviews, are depicted in Figures 1 and 2. At an early age (Year 1, 7–8 years old), most children's level of conceptual understanding was pre-elementary to basic (corresponding to Levels 1, 2 and 3). In Year 2 (8–9 years old), children displayed an elementary to basic level of conceptual understanding (corresponding to Levels 2 and 3). In Year 3 (9–10 years old), children's conceptual understanding was at its lowest, equating to a pre-elementary to basic level of conceptual understanding (corresponding to Levels 1, 2 and 3). At this stage, all children could name the sun and water as the key elements needed for plant growth (Levels 1 and 2), and a few of them specified which organ was involved in transporting the elements (Level 3).

Meanwhile, in Year 4 (10–11 years old), most of the children's responses on photosynthesis displayed a basic or partial level of conceptual understanding, and a peak at advanced conceptual understanding began to appear in children's interviews (corresponding to Levels 3, 4 and 5). In Year 5 (11–12 years old), children demonstrated an elementary, basic or partial level of conceptual understanding (corresponding to Levels 2, 3 and 4). At the end of primary school (Year 6, 12–13 years old), the children showed the most varied conceptual understanding, from elementary, to basic, partial and advanced levels (corresponding to Levels 2, 3, 4 and 5). At this stage, children who achieved Level 4 in conceptual understanding reflected the initial understanding of photosynthesis with some errors in their explanations. Meanwhile, children with an advanced level of conceptual understanding (Level 5) could incorporate all the elements of the photosynthesis process.

Year 6 also showed the most improvement in conceptual understanding via the interviews as most children shifted from elementary level (Level 2) in the drawings to basic and partial level (Levels 3 and 4) in the interviews. The level of children's conceptual understanding inferred from interviews was generally higher than that implied from the drawings across all age levels.

The average levels of conceptual understanding for all children in each schooling year were calculated to comprehensively understand photosynthesis across different primary school age

Table 4. Mean value of children's conceptual understanding.

	Mean value of conceptual understanding	
Year	Drawing	Interview
1	2.0	2.4
2	2.3	2.5
3	1.5	2.2
4	3.8	3.9
5	2.4	3.3
6	2.9	3.8

groups. The results of this calculation can be seen in Table 4 below. The study's findings reveal that, in general, the mean value level of children's conceptual understanding of photosynthesis improves with age, except for Year 3 and Year 4. Year 3 children had the lowest mean level of conceptual understanding, whereas, in contrast, Year 4 children recorded the highest level of conceptual understanding. The findings also reveal that interviews helped enhance the clarity of children's conceptual understanding when used in conjunction with their drawings. The mean value of conceptual understanding was higher in interviews compared to the drawings across all the age groups in this study.

Most importantly, the study indicates that interviews helped enhance the clarity of children's conceptual understanding when used in conjunction with their drawings. Figures 3 and 4 below show an example of this, representing a level 2 conceptual understanding of photosynthesis. The child's drawing portrays the basic elements needed for plant growth without indicating an understanding of photosynthesis. However, a follow-up interview based on the child's drawing revealed a partial understanding of the concept. In interview excerpt 1, the child had formed an understanding of the meaning of photosynthesis and how it was essential for plants to continue living through this process. Meanwhile, in interview excerpt 2, the child could list all the necessities plants require for photosynthesis: sunlight, air, water and chlorophyll.

Interview excerpt 1

R: How do plants ensure that they stay alive?
C: Hmmm … [Plants] making their own food.
R: Okay, plants make their own food. Can you pronounce this word?
C: Photosynthesis.
R: Do you know what is the meaning of photosynthesis?
C: Photosynthesis is when plants make their own food.
R: So when did you hear this word before?
C: [During] Year 4.
R: Where did photosynthesis occur?
C: At tree.
R: At tree. Can you specify? Where in plants does it occur?
C: At … I don't know.
R: You don't know. You only know it occurs in plants. But you don't know the specific place where it occurs. Okay, so why do plants need to do photosynthesis?
C: To continue living.

[S5/6]

Interview excerpt 2

R: How do plants ensure they stay alive?
C: There's someone to water it. Sunlight. Air. Soil.
R: Soil. Sunlight. Air. And someone to water it. Only four things. Is there anything else?
C: No.
R: Now I'm going to show you one word. Can you pronounce it?
C: Photosynthesis.
R: Have you heard this word before?
C: Yes.
R: Where have you heard this word before?
C: When I learn [science].
R: Do you know the meaning of this word?
C: Yes. Plant's food.
R: What do you understand about photosynthesis from plant food?
C: [Photosynthesis is] the process where plants make their own foods … I think it is made from chlorophyll … [It also requires] sunlight … [and] water.

[S6/4]

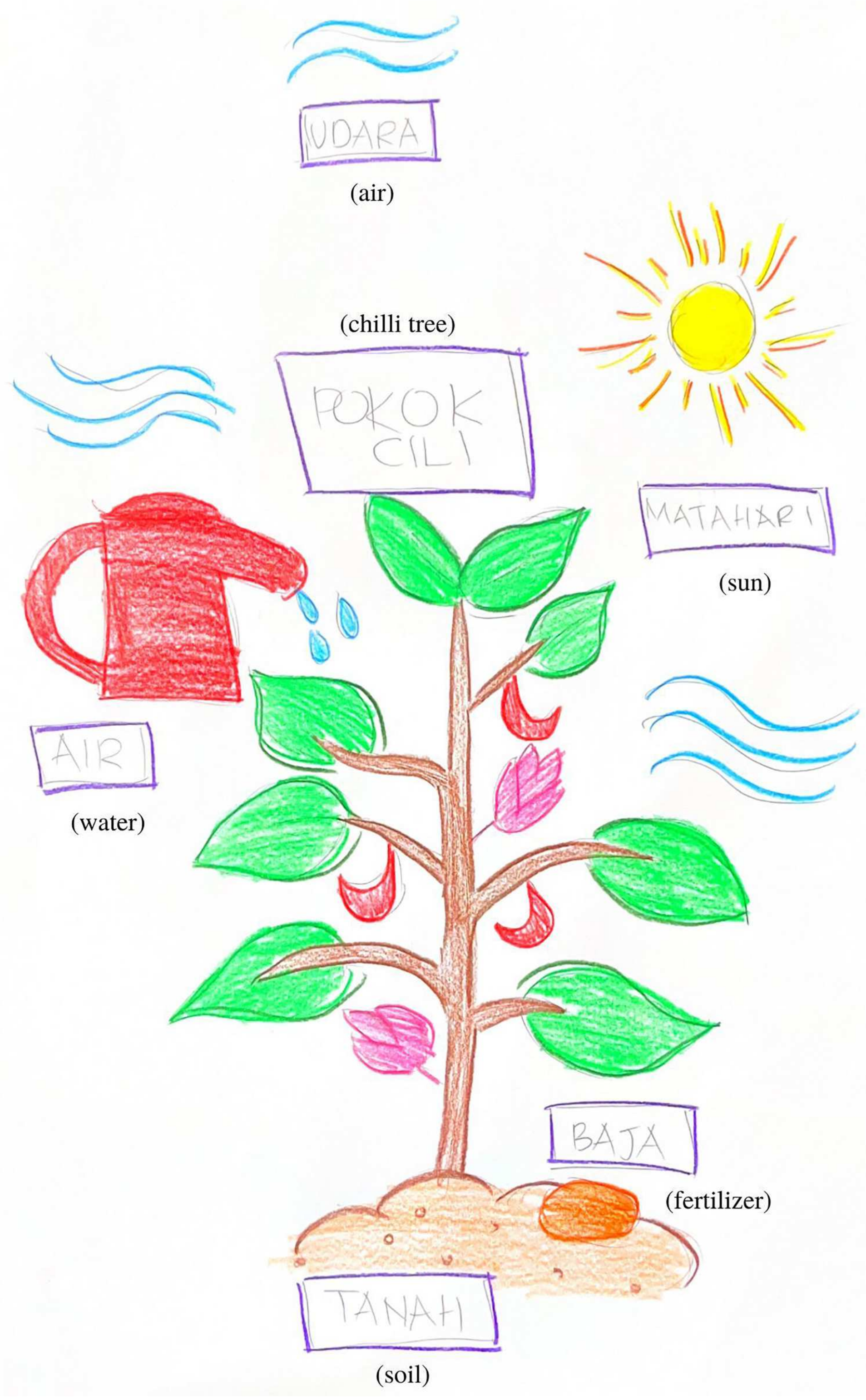

Figure 3. An example of an 11-year-old pupil's drawing [S5/6] with a level 2 conceptual understanding of photosynthesis.

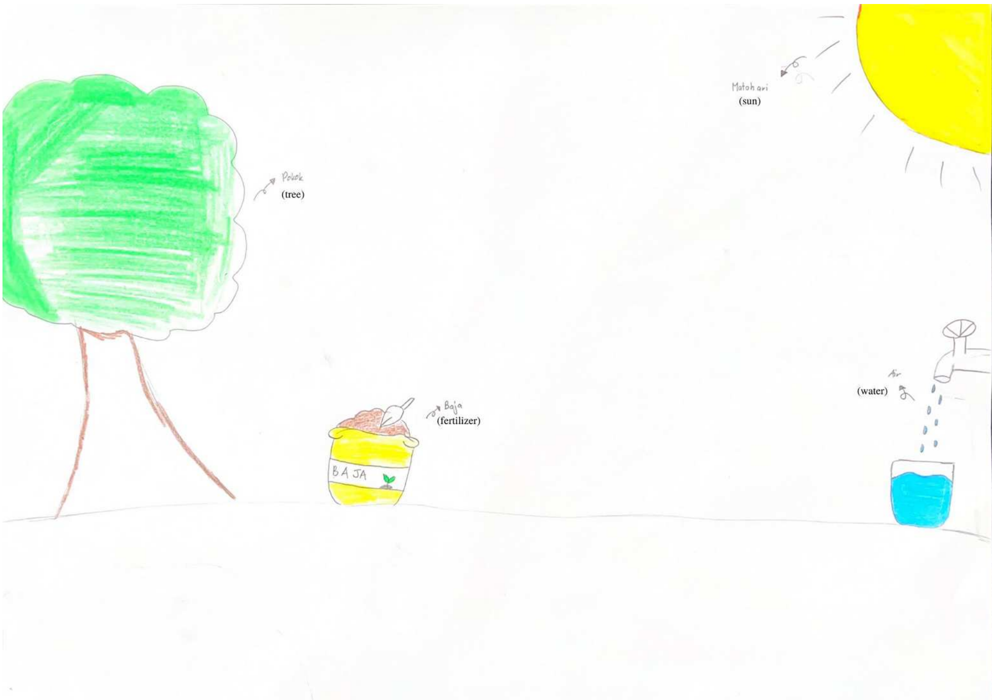

Figure 4. An example of a 12-year-old pupil's drawing [S6/4] with a level 2 conceptual understanding of photosynthesis.

Discussion

The aim of this study was to explore Malaysian children's conceptual understanding of photosynthesis across different primary school age groups. In general, the study's findings reveal that as children progressed through primary school, their understanding of the concept of photosynthesis improved. Due to the limited inclusion of the topic of photosynthesis in primary science curricula across many countries, the existing body of research examining primary children's understanding of this concept remains sparse. Moreover, this study delved into the developmental progression of children's conceptual understanding of photosynthesis throughout their primary education years, thereby necessitating the exclusion of a multitude of relevant research studies.

The present study replicated and extended previous findings by demonstrating similar results. Specifically, this study revealed a developmental pattern in children's conceptual understanding of photosynthesis, whereby improvement was observed with age, except for Year 3 and Year 4. Year 3 children had the lowest mean level of conceptual understanding, possibly due to the fact that the plant syllabus for that year primarily focused on plant reproduction. In the plant learning progression outlined by Allen (2016), after the children have learned about the requirements for plant growth, they move on to plant nutrition before exploring plant reproduction. This sequence is logical and effective as connections exist between the three covered topics that also match the way children naturally learn about scientific concepts. Furthermore, considering the complex nature of the topic of plant reproduction, which involves many interconnected curriculum strands, children typically acquire only a partial understanding and often harbour misconceptions (Stagg and Verde 2019). Therefore, it is difficult for Malaysian children to make connections between newly acquired and pre-existing knowledge.

In contrast, Year 4 children recorded the highest level of conceptual understanding, possibly because they had just recently learned about the topic of photosynthesis. Most children reported that they gained information from their teachers and trusted and accepted it, making them more inclined to understand and retain knowledge about the topic they had just studied (Enesco et al. 2017). The topic of photosynthesis was covered within a single school year, but the materials taught were not connected or consistent with the subsequent topics covered in years 5 and 6. This lack of continuity hinders children's ability to retain information about photosynthesis, which is vital for their overall understanding of science (Svihla, Wester, and Linn 2018). Furthermore, the lack of academic vocabulary retention and comprehension is particularly acute in the science content area. While some academic terminology overlaps with content areas, little of the science vocabulary is reinforced outside science class within the school curriculum, making retention and understanding even more challenging to achieve in the limited class time available (Shore, Ray, and Gooklasian 2015).

This study illustrates the dynamics of children's comprehension of photosynthesis as they embark on their primary school journey. While children initially possess a rudimentary grasp of plant growth processes, their conceptual understanding of photosynthesis can significantly evolve under the guidance of tailored science curricula and practical plant-related teaching approaches during their primary school years. As a result, this research not only underscores disparities in the levels of conceptual comprehension of photosynthesis among primary school students but also their implications for science educators. It highlights the imperative for science teachers to adapt their pedagogical strategies to offer structured assistance, as scaffolding helps children navigate their way from initial levels of comprehension to more complex levels (Songer and Gotwals 2012). It essentially acts as a temporary framework that supports children as they gradually acquire the knowledge and skills needed to achieve higher levels of proficiency related to photosynthesis.

In addition, this study underscores the significance of employing children's drawings and interviews as multimodal approaches for assessing children's conceptual understanding. Children construct explanations or solve problems by integrating ideas across diverse forms of representation such as drawings, verbalisations, and annotations, thereby demonstrating reasoning to a certain degree (Tytler et al. 2020). The study revealed that interviews were helpful in enhancing the clarity of children's conceptual understanding when used in conjunction with their drawings. While their drawings initially indicated minimal conceptual understanding, some children could articulate a more coherent connection to photosynthesis during the interviews. This highlights the importance of in-depth interviews as they provide additional information on children's understanding, in particular because young children may not fully have the language skills to express their knowledge through writing in their drawings (Gatt et al. 2007).

The method of using interviews, in addition to children's drawings, has been practised in some instances in the field of biology education. In Dikmenli's (2010) study, the interviews that were conducted with children after they had created drawings provided additional information on children's misconceptions about the carbon cycle. These misconceptions were not visible in children's drawings, but the interviews further revealed children's misconceptions as they were asked a series of questions to explain their drawings. Drawing practices were more familiar to children as participants, and thus were useful in this process. Additionally, Torkar et al. (2019) stressed that the technique of using children's drawings in conjunction with written responses or interviews is useful to gain insights into their conceptual or phenomenological understanding. The authors highlighted the strengths of both methods in conveying information, such as owls' physical components, sizes, and habitats, demonstrating how this information was shown more clearly through drawings. Meanwhile, children's written comments yielded more insights into their perceptions of their distinct behaviours, diet, and conservation status.

Meanwhile, in Andersson, Löfgren, and Tibell's (2020) study, during each drawing session, the children explained their designs to a facilitator and added written labels either themselves or, if they were unable to write, with the assistance of the facilitator. The study emphasised how important it is to provide children with the opportunity to clarify the meaning of their drawings; otherwise, it becomes a matter of the researcher's interpretation. The connections children make and their explanations of their drawings could have exciting implications for comprehending children's thoughts and thus could be useful for both science education instruction and research (Andersson, Löfgren, and Tibell 2020). Folsche and Fiebelkorn (2022) conducted an exploratory study on children's perspectives of rearing pigs and dairy cows on farms. In the study, semi-structured guided interviews were conducted to elicit children's conceptions, during which they drew and described a farm in detail. This method resulted in various children's perceptions, ranging from naive and objective concepts to clear conceptions of contemporary, conventional livestock.

Integrating interviews with children's drawings represents a highly effective and comprehensive approach to data collection that yields a richer understanding of children's perspectives in research contexts. This multifaceted method acknowledges the inherent limitations of relying solely on visual representations and leverages interviews as a complementary tool to provide depth and context to these visual expressions. By combining these two data collection methods, researchers can construct a more holistic and accurate portrayal of children's thoughts, perceptions and conceptualisations, ultimately yielding more informed and deeper insights into the views of young minds.

Conclusions

As children progress through their six years of compulsory primary education, their grasp of the intricate concept of photosynthesis undergoes transformative changes. These changes, however, hinge on the duration of their exposure to the subject, the specific plant-related topics they are introduced to, and the pedagogical techniques employed. This study underscores the importance of science educators selecting appropriate teaching methods when approaching the topic of photosynthesis. Teachers can enhance the depth of their understanding through incremental guidance by tailoring their pedagogy to the cognitive developmental stages of young learners (Kamarudin, Mat Noor, and Omar 2022). Concurrently, the primary science curriculum emphasises the significance of biology education researchers dedicating their efforts to exploring the intricate nuances of children's conceptual comprehension of photosynthesis. By doing so, they can uncover valuable insights into the most effective strategies to foster scientific literacy in the early stages of education by planning lessons based on children's initial ideas of scientific phenomena (Rybska, Tunnicliffe, and Sajkowska 2017).

Most importantly, we argue that the inclusion of follow-up interviews to supplement an exploration of children's drawings is important, thus underscoring the need for a multifaceted approach to assessing young children's scientific understanding. While drawings can provide a snapshot of a children's conceptions, they often lack the depth and context necessary to gauge the richness of their comprehension. This holistic approach acknowledges that proper awareness extends beyond the ability to reproduce information and focuses on nurturing a deeper, more enduring understanding of complex scientific concepts like photosynthesis. Overall, this study contributes to science and biology education research by offering a roadmap for effectively teaching photosynthesis to young children, aligning pedagogy and research for enhanced learning outcomes.

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Ethical consideration

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