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The pedagogical potential of drawing and writing in a primary science multimodal unit

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ABSTRACT

In consideration of the potential of drawing and writing as assessment and learning tools, we explored how early primary students used these modes to communicate their science understandings. The context for this study was a curricular unit that incorporated multiple modes of representation in both the presentation of information and production of student understanding with a focus on the structure and function of carnivorous plants (CPs). Two science teacher educators and two first-grade teachers in the United States co-planned and co-taught a multimodal science unit on CP structure and function that included multiple representations of Venus flytraps (VFTs): physical specimens, photographs, videos, text, and discussions. Pre- and post-assessment student drawings and writings were statistically compared to note significant changes, and pre- and post-assessment writings were qualitatively analysed to note themes in student ideas. Results indicate that students increased their knowledge of VFT structure and function and synthesised information from multiple modes. While students included more structures of the VFT in their drawings, they were better able to describe the functions of structures in their writings. These results suggest the benefits for student learning and assessment of having early primary students represent their science understandings in multiple modes.

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Science units for primary students that integrate hands-on science explorations with language arts skills have shown potential for increased learning in both subjects (Bradbury, 2014; Varelas, Pieper, Arsenault, Pappas, & Keblawe-Shamah, 2014). As an extension, science educators have become increasingly interested in the potential that using multiple modes of communication in science units has to promote deeper science conceptual understanding (McDermott & Hand, 2015). By integrating multiple modes of representation (including text, image, gestures, mathematics, and kinesthetics) into both the presentation of science content and the production of science understandings, students are conceptually pushed to synthesise information from different sources, which is considered a crucial step in science learning (Hubber, Tytler, & Haslam, 2010). When teachers engage students with science content using multiple modes, these various representations can (a)

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exhibit complementary processes or information, (b) constrain interpretation of content, and/or (c) aid in constructing deeper understanding of content (Ainsworth, 1999). Incorporating multiple modes into a science unit enhances what knowledge students are able to construct through analysis and evaluation of various resources in addition to how they are able to represent and communicate their understandings (Waldrip, Prain, & Carolan, 2010).

In the era of the National Science Education Standards (National Research Council, 1996), constructing representations was a component of reform-based science teaching (Coleman, McTigue, & Smolkin, 2011) and remains a critical aspect of several of the practices in the *Next Generation Science Standards* (*NGSS*) for early primary students (NGSS Lead States, 2013). Researchers have noted the important role that being able to interpret and construct representations of science knowledge plays in students' science literacy development (Prain & Waldrip, 2010). The *NGSS* practices related to scientific communication of developing and using models, analysing and interpreting data, and obtaining, evaluating, and communicating information each contain targets for K-2 students that involve them in constructing representations through images and text (NGSS Lead States, 2013). In addition, the practices of analysing and interpreting data and obtaining, evaluating, and communicating information for K-2 students encourage the sharing of science understandings through writing.

It has been argued that having students construct drawings, in addition to writing, has the potential to be a critical link in students' science learning (Prain & Tytler, 2012). Researchers have argued that drawing should be recognised along with reading, writing, and speaking as a means: (a) to enhance engagement, (b) to represent science, (c) to reason, (d) as a learning strategy, and (e) to communicate (Ainsworth, Prain, & Tytler, 2011). There is an emerging line of research into how the use of drawings with primary students can be used to understand their thinking about science topics, as the act of drawing is a part of the learning construction process (Cox, 2005; Van Meter, Aleksic, Schwartz, & Garner, 2006). There have been studies exploring early primary students' decisions when making science drawings (e.g. Lundin & Jakobson, 2014), as well as the use of drawings as an assessment tool for early primary students (e.g. Rybska, Tunnicliffe, & Sajkowska, 2014). However, research focusing on the potential learning opportunities for students when they construct representations in science has largely focused on upper primary, secondary, and university students (Choi, Notebaert, Diaz, & Hand, 2010; Hand & Choi, 2010; Hubber et al., 2010; McDermott & Hand, 2013; Tytler, Prain, & Peterson, 2007; Waldrip et al., 2010). Similarly, the research on the benefits of having students include writing in science units has been conducted mostly at the upper primary, middle, secondary, and university levels (Hand, Gunel, & Ulu, 2009; Klein, 2000; McDermott & Hand, 2013; Rivard, 1994).

In consideration of the potential roles of drawing and writing as assessment and learning tools, we were interested in how early primary students used these modes to communicate their science understandings. The context for this study was a curricular unit that incorporated multiple modes of representation in both the presentation of information and production of student understanding with a focus on the structure and function of carnivorous plants. Therefore, we asked the following research question: How did first-grade students represent their science understandings of carnivorous plant structure and function in drawings and writing?

Theoretical framework

We are drawing on the theoretical framework of Representational Construction Affordances because of its consideration of semiotic, epistemic, and epistemological aspects of analysing, constructing, and re-representing understandings of science knowledge (Prain & Tytler, 2012). In their figure of the nesting factors related to how students can learn by constructing representations in science, Prain and Tytler (2012) place semiotic tools as the largest circle, which incorporates the influences of both material and symbolic tools available to students while they are learning about a science topic. The epistemic level is nested as a smaller circle within semiotic tools and focuses on the practices that students are engaged in while studying science topics. The epistemological activity is nested within the epistemic level and is focused on the cognitive activities that students are engaged in as a result of the tools and practices they are involved in while thinking about a particular science topic. Prain and Tytler (2012) assert that recognising all of these factors and how they are involved when students construct representations in science, such as drawings and writing, gives researchers tools to understand why such a pedagogical strategy can result in deeper science learning.

Literature review

Plants

In studies exploring primary-aged children's knowledge of plants, the results have shown a lack of knowledge of wild plants (Anderson, Ellis, & Jones, 2014; Patrick & Tunnicliffe, 2011) and misconceptions of the needs of plants as living organisms (Barman, Stein, McNair, & Barman, 2006). Early primary children more often named domesticated and farmed plants than wild plants when asked to name as many plants as they could (Patrick & Tunnicliffe, 2011). When asked to draw plants showing their parts and things that a plant needed to grow, kindergarten and first-grade students frequently drew plants with flowers and stems, but without leaves or roots (Anderson et al., 2014). In a survey of 869K-2 learners, most were able to identify the needs of plants but often discussed the function of these needs as similar to humans rather than their true function (e.g. light for warmth rather than as a key element in photosynthesis) (Barman et al., 2006). When exploring student drawings illustrating plant needs, about a third of students' drawings included sun, less than a third rain and soil (Villarroel & Infante, 2014). These findings support the need for primary science units to help students develop knowledge of plants as living organisms in non-human controlled environments with parts that function to help them meet their needs. In addition, Anderson et al. (2014) note that research on the use of drawings within a curricular unit on plants has not been done.

In various learning environments, however, researchers have found that primary students focus almost exclusively on the structures of plants over the functions of these structures or the needs of plants as living organisms (Kos & Jerman, 2015; Tunnicliffe, 2001; Tunnicliffe & Reiss, 2000). When 7-, 9-, and 11-year-old children had spontaneous conversations at botanical garden visits, Tunnicliffe (2001) found that they hardly discussed the functions of plants compared to anatomical features. Students aged 5, 8, 10, and 14, when giving names to 6 chosen plants, most often used aspects of the plants' anatomy more than the function, habitat, or form of the plant in classifying them and did not connect the anatomical features of the plant as adaptations for their habitat type (Tunnicliffe & Reiss, 2000). When observing wild flowering plants in a school setting, preschool and kindergarten-aged children focused on the colour of the plant and flower as the most important characteristics, followed by shape, and then by size (Kos & Jerman, 2015). These recent studies support Askham's (1976) findings that upper primary students, when classifying plants in outdoor settings, focused on anatomical features, such as size, shape, colour, form, and parts.

Relatively little is known about primary student knowledge of carnivorous plants. Anecdotally, however, educators have noticed student interest in and enthusiasm for learning about carnivorous plants in informal settings (Golembiewski, 2005; Tunnicliffe, 2001). When asked if the Venus flytrap (VFT) is a plant, 36% of first graders in rural southeastern classrooms correctly classified it as a plant (Anderson et al., 2014). Yet, in a national study of K-2 students, 73% were able to correctly classify the VFT as a plant (Barman et al., 2006). In one of the few studies where physical specimens of carnivorous plants are included, Tunnicliffe (2001) noted that in spontaneous conversations at botanical garden visits, 19% of these conversations discussed food/feeding functions of plants, mostly in regards to carnivorous plants. Therefore, a study of primary students' knowledge and understanding of carnivorous plant structure and function within a curricular unit contributes to a gap in the research literature.

Drawing

While many primary teachers show graphical representations in their science teaching, relatively few have students produce drawings as a part of their science instruction (Coleman et al., 2011). Drawings are, however, increasingly being used as a tool to examine younger students' understandings of a particular science topic. Incorporating drawings into instruction for early primary students has been advocated as a window into student thinking (Cox, 2005; Einarsdottir, Dockett, & Perry, 2009). Cowie and Otrel-Cass (2011) used drawings to capture five-year-old students' ideas about animal life cycles. In a study with 9- and 11-year-olds, Bowker (2007) used drawings to investigate children's perspectives of tropical rain forests. Lundin and Jakobson (2014) explored how eight-year-old students in Sweden drew diagrams of the human body. Ehrlen (2009) used drawings to probe 6- to 9-year-old students' perceptions of the Earth. Drawings of plants have been used to identify students' knowledge of plants as living things with their needs, such as sun, rain, and soil (Anderson et al., 2014; Villarroel & Infante, 2014), in addition to plant parts (Anderson et al., 2014). In each of these research studies, drawings have been a method to encourage student communication of their ideas in multiple science content topics, making them a valuable tool for assessment (Waldrip et al., 2010).

When teachers enact tasks that involve drawing, they include different levels and types of support that impacts what students include in their science drawings. For example, in a mixed first- and second-grade classes, a paper with a basic level of organisation given to students for their drawings had a significant positive impact on whether collaborative groups constructed detailed and relevant constructions of the life cycle of a sea turtle (Danish & Saleh, 2014). K-2 students' drawings of pollination were influenced by how the teacher framed the drawing task in regards to audience and the scientific purpose of the drawing (Danish & Enyedy, 2007). In a study of fourth- and sixthgrade students, four conditions were established that involved varying levels of support (Van Meter et al., 2006). The students in the most supported condition investigated birds' wings by reading about them, looking at illustrations, drawing the wing, and completing a series of questions that asked the students to compare their drawing to the illustration. These most supported students had the highest performance on a post-test about the content as compared to students in conditions with less scaffolding.

One conclusion that emerges from multiple researchers investigating drawing with primary students is the importance that the actual construction of the drawing has on student learning as they synthesise their understandings of science topics. Several researchers describe drawing as a constructive learning process in which students integrate information from the available representations in order to portray their understanding (Chang, 2012; Cox, 2005; Danish & Enyedy, 2007; Van Meter & Garner, 2005). An emerging idea is that the integration of multiple representations (image, text, physical models, etc.) into a science unit requires students to reconcile and fuse information into one constructed product, thereby increasing their understanding of the science content they are studying (Van Meter et al., 2006).

Writing

Researchers have found that writing can serve as a tool to help students construct understandings of science concepts when certain conditions are in place (Hand et al., 2009; Klein, 2000). When students in grades 4, 6, and 8 used certain strategies during their writing, including brainstorming, reviewing text, and reviewing experiences from investigations, they learned more from the writing process than those who did not use those approaches (Klein, 2000). Additionally, hands-on observations provided support for seventh-grade students as they wrote about science (Wallace, 2004). In interviews, these students described how the process of connecting their laboratory experiences with their textbook and then writing about it enhanced their understanding. Rivard and Straw (2000) found that eighth-grade students who engaged in discussions with peers prior to writing were able to retain more information over time than those who only talked or only wrote about their learning. The participants in Rivard and Straw's (2000) study used their peer discussions as a way to clarify and share knowledge. Subsequently, during the writing process they organised their ideas into a more coherent and systematic representation.

Just as researchers have indicated that drawing is an important tool for knowledge construction in science (e.g. Van Meter & Garner, 2005), others have observed that writing can serve as a tool for knowledge building (e.g. McDermott & Hand, 2013). For seventh-grade students engaged in two units (cells and microorganisms), the most successful students were those who were able to integrate information from multiple sources into a coherent whole in their writing (Wallace, 2004). When 10th-grade Turkish students were asked to embed mathematical representations into their writing about electricity, they scored significantly higher than those who did not (Hand et al., 2009). Therefore, asking students to represent their understandings in multiple modes resulted in higher learning gains. Hand et al. (2009) state, 'Writing is an epistemological tool in that it requires students to take existing knowledge and build richer connections between different elements of this knowledge through the process of writing' (p. 228). It can be argued that having students integrate multiple modes when they create products of their learning through writing results in deeper learning because students are involved in more sophisticated cognitive activity (Prain & Tytler, 2012).

Drawing and writing

Little research has focused on writing in science and even fewer studies examine the effect of drawing and writing together in science. While some researchers describe science units in which primary students are engaged in using both drawings and writings to record their ideas, few analyse the types of information included in these modes or how these modes may help students construct knowledge. For example, Aschbacher and Alonzo (2006) found that primary students' science notebook scores (which included drawings and writings) predicted their outcomes on other assessment measures including a content post-test. However, they did not present analysis of student drawings versus their writing. In a study investigating the effects of using drawing before writing as a scaffold for 8- to 9-year-old English language learners, Adoniou (2013) found that drawing a step-by-step process helped students include more details in their written versions of the process. However, Adoniou (2013) focused on the role of drawing only as a supporting practice for writing and did not explore how drawing itself was used as a communication tool in science compared to writing.

Such studies comparing drawing and writing and their roles in science instruction are few and have been conducted above the primary level. When presenting science content in both writing and drawing, university students gained more knowledge from drawings and diagrams than from text (Ainsworth & Loizou, 2003). In communicating their science understandings, secondary and university students were better able to show technical information in drawings and process information in writing (Akaygun & Jones, 2014). Therefore, Akaygun and Jones (2014) found that the most useful mode of communication of science ideas was dependent on the type of information that students were representing. Based on this emerging research comparing drawing and writing in science, there is evidence that the context has an influence on the facility of the mode of communication for expressing science understandings.

Given the promise of both drawing and writing as potential modes for students to synthesise and share science information that results in deeper learning, there is a lack of research at the early primary level examining these claims. Therefore, the purpose of this study is to explore what first-grade students are able to communicate through both drawing and writing in a unit on plant structure and function. By comparing the type of information they included in both of these modes, we will explore how their science understandings changed as a result of participating in a multimodal unit focused on carnivorous plants.

Methods

Context

Two science teacher educators and two first-grade teachers co-planned and co-taught a multimodal science unit on carnivorous plant (CP) structure and function that was integrated with Common Core English Language Arts skills. The first-grade teachers work in a rural, public, Title 1 primary school in the southeastern United States. Each teacher had 21 students with consent to participate in the study, resulting in a total of 42 students in the study. Thirty-one of the 42 students whose parents gave consent for them to participate in the study completed all of the work within the CP unit.

The CPs unit was designed as a multimodal 5E (Bybee et al., 2006) on plant structure and function that engaged first graders in using a variety of semiotic tools: viewing physical specimens of, reading and writing about, viewing photographs and videos of, and drawing carnivorous plants, including the VFT, pitcher plant, and sundew. CPs were chosen as the focus for the first-grade unit on plant structure and function because features such as distinct leaves are more noticeable and stimulating to young children (Askham, 1976; Tunnicliffe, 2001). In addition, providing physical specimens of wild plants into primary classrooms has been noted as a need to develop understandings of the link between unique structures and their function for the plant in its particular habitat (Patrick & Tunnicliffe, 2011). This multimodal, integrated science and language arts unit was designed to meet NGSS and Common Core English Language Arts standards for first grade (students aged 6–7 years). In the state in which the students live, there are no grade-level curricular expectations for understanding plant structure and function previous to first grade. In addition, the unit asks students to participate in multiple epistemic practices by incorporating Science and Engineering Practices (NGSS Lead States, 2013), such as developing and using models, analysing and interpreting data, and obtaining, evaluating, and communicating information. Our approach for the use of drawing in this unit was as a communication tool, a scaffold for facilitating writing, and an assessment for students' knowledge growth. Including multiple representations of CPs throughout the unit was intentional in order to support developing conceptual understanding of plant structures and how they function (Carolan, Prain, & Waldrip, 2008; Hubber et al., 2010).

Given that children make drawings for specific purposes (Lundin & Jakobson, 2014), we clearly articulated that the type of drawing that students were to construct represents what CPs actually look like when they observed them and saw them in pictures and videos. We were explicit that the children should use colour and labels to add as much detail as possible to the drawings of the plants in both the initial and final drawings. While student drawings and writings were used in the unit as a form of pre- and post-assessments, students were involved in drawing, writing, reading, observing, and discussing representations of VFTs and other CPs every day during the unit in order that no one representation was seen as the one correct model (Hubber et al., 2010). For further elaboration on the implementation of the unit, see Bradbury, Wilson, Pepper, and Ledford (2016).

VFTs plants (*Dionaea muscipula*) were chosen as the focus plant for assessment of student understanding of plant structure and function during this unit. VFT plants, like other CPs, grow in wet, acidic, nutrient-poor soil, and flourish if they can trap and digest insects for supplemental nutrition (Adamec, 1997). The VFT grows modified leaves to lure and catch prey. The end of the leaf is described as the trap where it splits into two flattened discs. Each disc has spines protruding vertically from the edge of the trap. On the inside surface of each trap, there is a red tint and glands that produce a sweet-smelling nectar, both of which lure insect prey. Once the insect lands on the inside surface of the trap, they can come into contact with trigger hairs. When the prey touches one trigger hair twice or two trigger hairs in short succession, the trap begins to close, with the spines on the top edge of the trap preventing the prey from escaping (Williams, 1980). The trap produces digestive juices that break down the prey and the nutrition is absorbed through the surface of the trap.

Data collection

Data collection from the week-long unit includes student work from the unit and post-unit reflections with the classroom teachers. Student work from the unit was scanned and returned to the classroom teacher. Audio files from the post-unit reflection were transcribed.

Students may have started the unit with previous knowledge of plant structure and function, in addition to knowledge of VFT. Students live in a community in which families have historically farmed or kept household gardens; therefore, they may have some previous knowledge of plants parts and growth. The school that they attend has a school garden and some students may have participated in yearly seed planting in their earlier primary experiences. In addition, VFT plants, at the time of the study, were available for purchase at a local hardware and plant nursery store. Therefore, on the first day of the unit, students were asked to observe physical specimens of the VFT plant and make a drawing that would show what they saw. Students were also asked to write words to describe the plant (structure) and predict which part(s) of the plant would allow the plant to catch an insect (function). The student work from the first day of the unit will be described in the rest of this article as the pre-unit assessments. These pre-unit assessments help to document what knowledge and understanding students may have brought into the unit of VFT plant structure and function.

On the final day of the unit, students were asked to draw the VFT from memory and label the parts on their drawing. They were also asked to complete three sentence stems: (1) I noticed that the Venus flytrap has … (structure) (2), These characteristics help the Venus flytrap to … (function), and (3) I think it is cool that the Venus flytrap … (structure and/or function). The student work from the final day of the unit will be described in the rest of the article as the post-unit assessments.

Data analysis

We compared the 31 student drawings and writings from the initial observations (pre-assessment) made of the physical specimens to end-of-unit drawings and writings about the VFT (post-assessment).

Drawing

Primary student drawings have been analysed for the presence of science components before and after an instructional event (Bowker, 2007). Content analysis on such drawings by students can be used in investigating both qualitative and quantitative patterns to gather information about what students are thinking about in relation to a particular topic (Merriman & Guerin, 2006).

We looked for patterns of inclusion of eight features of VFT structures across individual student work. The eight structures of a VFT that we looked for in student drawings were the presence of: a flower, trap(s), stem(s) to traps, spines, trigger hairs, red in the middle of the trap(s), green colour on trap(s), and an insect. We chose these features because they were all visible on the physical specimens and/or in the photographs and videos included in the unit. We counted the number of features labelled or drawn by each student as included (1) or not present (0). We used these numbers in two different analyses.

First, we totalled the number of structures that each individual student included in both the pre-assessment and post-assessment drawings, resulting in a number ranging from 0 to 8 for each student. Figure 1 shows two examples of student drawings from the pre-assessment (Students 15 and 27), each showing a score of 3. Figure 2 shows two examples of student drawings from the post-assessment (Students 10 and 20), each showing a score of 6. SPSS version 22 was used to analyse the mean number of structures present in student drawings for both pre- and post-assessment drawings with the standard deviation.

Second, we also looked across students to calculate the frequency of the inclusion of each structure in the pre- and post-assessment drawings. We were interested in whether or not students' inclusion of each of the eight structures of the VFT plant changed from the beginning of the unit when they initially observed the plant to after the unit. If the unit had no effect, then the number of students who did not include a structure before the unit and included the structure after the unit should be approximately the same as those students who included a structure before and did not include the structure after the unit. Therefore, the null hypothesis was the number of students going from non-inclusion (0) to inclusion (1) is the same as the number of students going from inclusion (1) to non-inclusion (0). Because we collected data in a pretest/post-test design with dichotomous dependent data where there was a treatment between pretest/post-test, we applied the McNemar test (Siegel & Castellan, 1988). To determine whether or not to reject or keep the null hypothesis, we analysed the data using SPSS version 22 to determine the binomial distribution between the pretest/post-test frequencies, with significance of change from pretest to post-test indicated by a $p < 0.05$ and a change approaching statistical significance indicated by between $p < 0.1$ and $p < 0.05$.

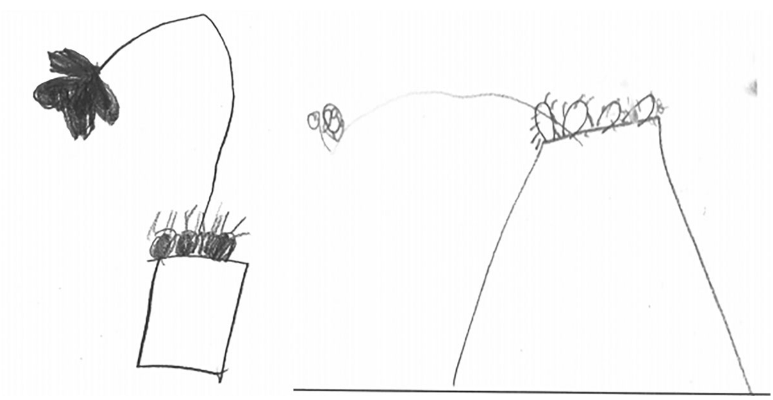

Figure 1. Examples of student drawings from the pre-assessment.

Figure 2. Examples of student drawings from the post-assessment.

Writing

In addition to analysing the student drawings in the pre- and post-assessments, we also analysed the writing that accompanied their drawings. For the pre- and post-assessment writing, we noted the words that the students included to describe the structures that the plant possessed. For each student's writing that described structures and/or functions of the VFT in both the pre- and post-assessments, we totalled the number of elements that each individual student included in both the pre-assessment and post-assessment writing, resulting in a number ranging from 0 to 12 for each student. The 12 elements of a VFT that we looked for in student writing were the presence of: a flower, spines, trap(s), trigger hairs, red in the middle of the trap(s), green colour on trap(s), an insect, nectar, and an action verb(s). We chose these elements because they are all features that contribute to the VFT luring and capturing prey, except for action verbs. We included this element because we were interested in whether students were able to make a connection between a structure and its function in luring and capturing prey. When coding the writing, we also noticed the inclusion of terms by students such as mouth, teeth, and leaves. These 3 elements were added to make the total number of elements 12. We then analysed the data using the McNemar test to determine if there was a significant change in inclusion of elements in student writing.

We also analysed the pre- and post-assessment writing that focused on student ideas about what the plants used their unique features to do. We qualitatively coded student responses in the pre- and post-assessment writing and noted trends in student thinking using constant comparative methods (Charmaz, 2007). We grouped student responses based on whether they only listed structures or if they used action verbs to describe the function of a structure. When the students used action verbs, we grouped their responses based on whether they described general functions (meeting needs) as separate from specific functions (catching prey). Table 1 shows the qualitative codes that we developed to analyse student writing with examples from student work.

Table 1. Qualitative coding for writing with examples.

	Describing structures	Describing function		
Data source	**Structures ($n = 14$)**	**Meeting needs**	**Catching prey ($n = 14$)**	
Pre-assessment writing (prediction prompt)	it got spuiks on it it has very shorp fangs the mouths	N/A	the needls will chomp the bug the malth closis the spicks clos on the insects	
Data source	**Structures ($n = 5$)**	**Meeting needs ($n = 11$)**	**Catching prey ($n = 12$)**	
Post-assessment writing (sentence stem 2: These characteristics help the VFT …)	has spikes	digest the insect	the spikes help it new that a insect	
	Flowers	to eat bug	to trap the insects	
	trigger hairs	get food	cach its pry	
Data source	**Structures ($n = 4$)**	**Carnivorous ($n = 6$)**	**Can catch insects ($n = 14$)**	**Moves ($n = 4$)**
Post-assessment writing (sentence stem 3: I think it is cool that the …)	Has spikes Has teeth	Eats bugs Digest insects	Can snap shut Close the spikes	Moves Can move

Findings

Drawing

The mean number of VFT structures that students included in the pre-assessment drawing was 3.42 with a standard deviation of 1.29. The mean number of structures that students included in the post-assessment drawing was 5.19 with a standard deviation of 1.30. In the group of students who were identified by their teacher as below grade level for reading, nine improved from the pre- to the post-assessment drawing, while one included the same number of elements in both assessments, and zero decreased the number of elements in the post-assessment drawing. For students who were identified as at grade level for reading, 10 showed growth from the pre- to the post-assessment drawing, 2 showed no change in the number of elements included, and 1 student included fewer elements in the post-assessment drawing. In the group of students who were identified as above grade level for reading, all eight students showed improvement with an increase in the number of elements from the pre- to the post-assessment drawing. Data for each individual student's score on the pre- and post-assessment drawing are included in Table 2.

Results from the McNemar statistical analysis are shown in Table 3. When the results were analysed in SPSS using the McNemar test, students showed significant differences in their inclusion of trigger hairs ($p = 0.001$), the colour red in the middle of the trap ($p = 0.000$), and the inclusion of an insect ($p = 0.008$) from their pre-assessment to the post-assessment drawing. Twenty students did not include trigger hairs in their pre- or post-assessment drawings, but 11 students added it in their post-assessment drawing. Four students included red in the middle of the trap in their pre- and post-assessment drawings, while 20 students added it to their post-assessment drawings. Twenty-two students did not include insects in their pre- or post-assessment drawings, but eight students added it in their post-assessment drawing. Students showed differences that are approaching significance in their inclusion of the colour green ($p = 0.057$) and spines ($p = 0.065$) on the trap. Eleven students included the colour green on the traps in both the pre- and post-assessment drawings, and 11 added it to their post-assessment drawings. Eighteen students included the spines on the trap in both the pre- and post-assessment drawings, while nine students added the spines to the traps in the post-assessment drawings.

Table 2 . Pre- and post-assessment drawing scores.

Student	Pre-assessment drawing score	Post-assessment drawing score	Difference in scores
1	3	5	2
2	3	4	1
3	3	4	1
4	1	4	3
5	6	6	0
6	2	6	4
7	5	6	1
8	6	6	0
9	4	6	2
10	5	6	1
11	3	5	2
12	4	6	2
13	3	7	4
14	2	3	1
15	3	4	1
16	3	5	2
17	3	4	1
18	3	1	−2
19	5	5	0
20	2	6	4
21	2	6	4
22	4	5	1
23	4	5	1
24	4	5	1
25	5	6	1
26	4	6	2
27	3	5	2
28	2	6	4
29	4	8	4
30	4	6	2
31	1	4	3

Writing

Quantitative results

The mean number of elements that students included in the pre-assessment writing was 2.03 with a standard deviation of 1.25. The mean number of elements included in the post-assessment writing was 3.52 with a standard deviation of 1.29. In the group of students who were identified by their teacher as below grade level for reading, seven improved

Table 3. McNemar test statistics for pre- and post-drawing and writing assessments.

Inclusion of element pre- and post-	Drawing exact significance (two-tailed)[a]	Writing exact significance (two-tailed)[a]
Flower	0.508	0.424
Trap	1.000	1.000
Stem to trap	0.508	n/a
Spines	0.065	0.454
Teeth	n/a	0.70
Mouth	n/a	0.008*
Leaves	n/a	0.008*
Trigger hairs	0.001*	0.000*
Red in the middle of trap	0.000*	1.000
Green colour	0.057	0.001*
Nectar	n/a	0.016*
Insect	0.008*	0.077
Action verbs	n/a	0.002*

[a]Binomial distribution used.
*$p < 0.05$.

from the pre- to the post-assessment writing, while one included the same number of elements in both assessments, and two included one fewer element in the post-assessment writing. For students who were identified as at grade level for reading, nine showed growth from the pre- to the post-assessment writing, four showed no change in the number of elements included, and zero students included fewer elements in the post-assessment writing. In the group of students who were identified as above grade level for reading, six showed improvement with an increase in the number of elements from the pre- to the post-assessment writing, zero showed no change, and two included fewer elements in the post-assessment writing. Data for each individual student's score on the pre- and post-assessment writing are included in Table 4.

Results from the McNemar statistical analysis are shown in Table 3. When the results were analysed in SPSS using the McNemar test, students showed significant differences in their inclusion of 6 of the 12 elements. For three of the six elements, students showed a significant increase in inclusion from the pre-assessment to the post-assessment. These increased elements included the trigger hairs ($p = 0.000$), nectar ($p = 0.016$), and the use of action verbs ($p = 0.002$). Zero students included trigger hairs or nectar in their pre-assessment writing prompt, but 22 students included trigger hairs and 7 students included nectar in their post-assessment writing prompt. One of the elements that students showed a significant increase in use from their pre-assessment to the post-assessment writing was the use of action verbs. The use of action verbs in writing was scored as present when students did not merely list structures or elements, but wrote sentences including an action

Table 4. Pre- and post-assessment writing scores.

Student	Pre-assessment writing score	Post-assessment writing score	Difference in scores
1	2	4	2
2	3	5	2
3	3	5	2
4	3	2	−1
5	0	4	4
6	2	3	1
7	4	4	0
8	3	3	0
9	5	2	−3
10	3	4	1
11	2	5	3
12	2	4	2
13	0	5	5
14	1	0	−1
15	0	4	4
16	2	4	2
17	1	4	3
18	1	2	1
19	1	4	3
20	1	3	2
21	3	3	0
22	2	3	1
23	1	4	3
24	4	4	0
25	3	5	2
26	1	5	4
27	3	3	0
28	3	0	−3
29	1	4	3
30	2	3	1
31	1	4	3

verb that linked the attribute to how the plant used that element to survive. Fourteen students included an action verb in the pre-assessment writing, and 27 included an action verb in the post-assessment writing.

For three of the six significant elements, students showed a significant decrease in the inclusion of these from the pre-assessment to the post-assessment: mouth, leaves, and green colour on trap. Eleven students included the word green in their pre-assessment writing and only one student included the word green in their post-assessment writing. Eight students included the word mouth in their pre-assessment writing and zero students included mouth in the post-assessment writing. Eight students included the word leaves in their pre-assessment writing while zero students included leaves in the post-assessment writing.

Pre-writing qualitative results

When students were asked to predict which part of the VFT would help the plant catch an insect, 3 students did not respond, 14 students listed structures (e.g. spikes or mouth), and 14 students listed structures in a sentence that described an action that the plant would engage in to capture an insect (e.g. the sharp teeth help it get its food or the needles will chomp bug). When students were using words like mouth and teeth/needles/spikes, they were referring to a part of the plant they could easily observe but did not yet have the correct scientific vocabulary to name (i.e. trap and spines).

Post-writing qualitative results

The second sentence stem in the post-assessment writing asked students what the structures they had listed in sentence stem 1 enabled the VFT to do. When coding the post-assessment writing samples from students, 23 students responded correctly with an action verb describing a function. Of these 23 students, 12 wrote that the plant was using its structure to catch prey animals. Seven of these 12 used the word 'catch,' while 3 used 'trap,' and 2 used 'know.' In this case, a response of 'know' demonstrates accurate science understanding from the first-graders because the first step in the process of capturing an insect is for the plant to recognise that the insect is present. Of the 23 function responses, 11 students recognised that the plant was using structures to meet its needs. However, eight of these demonstrated the common misconception that these parts allow it to 'eat,' while three of these used the more complex and accurate science vocabulary 'digest.' Five students listed another structure with no description of its function and three students did not write a second sentence.

The third sentence stem in the post-assessment writing asked students what they thought was cool about the VFT. It was left to the students whether they wanted to respond with a structure or a function or both that they thought was particularly interesting. When analysing the 'cool' sentence, 4 students noted the novelty of the VFT moving, 4 students listed a structure, 20 students wrote about functions related to VFT being carnivorous or catching insects, and 3 did not write a third sentence.

When comparing individual students' responses to sentence stems 2 and 3, 19 students correctly completed the second sentence stem with a function and also included a function for their third sentence stem. Three students correctly completed the second sentence stem with a function, but chose to list a structure for the cool sentence stem. Five students incorrectly completed the second sentence stem with a structure; however, they listed a function for their cool sentence stem. One student did not list a function for either sentence 2 or 3; rather they only listed structures for each sentence. The same three students did not write a sentence after the first one; therefore, they had no response to analyse for sentence stem 2 or 3.

Drawing and writing

In comparing student work for the drawing and writing, most students, regardless of teacher-described reading level, increased in the number of elements they included in their post-assessment as compared to their pre-assessment. For example, 27 out of 31 students increased the number of elements in their drawings from pre- to post-assessment, while 22 out of 31 students increased the number of elements in their writing from pre- to post-assessment. In addition, there were similarities in the content related to trigger hairs and the presence of insects. First, when statistically analysing the changes in students' inclusion of trigger hairs from the pre- and post-assessments, in both their drawing ($p = 0.001$) and writing ($p = 0.000$), the number of students who included trigger hairs was significantly greater in the post-assessments. Second, in both the drawing and writing post-assessments, there was an increase in the number of students ($n = 8$) who included the presence of an insect. In the drawing analysis, this increase was statistically significant ($p = 0.008$) while in the writing, this increase was approaching statistical significance ($p = 0.077$).

There were more differences in the student drawings and writing than there were similarities. For example, there was a significant increase in the number of students who included nectar in the post-assessment writing ($p = 0.016$), while zero students included nectar in their drawings. Similarly, there was a significant increase in the number of students who included action verbs in their writing post-assessment ($p = 0.002$), but zero students represented action in their drawings.

Another difference between the drawing and writing results was the presence of green in student work. In the pre-assessment writing, 12 students included the word green, while in the post-assessment writing, 1 student included the word green, which resulted in a statistically significant decrease in the inclusion of green in student writing ($p = 0.001$). In the pre-assessment drawing, 14 students included green and 22 students included green in their post-assessment drawings, resulting in an increase in the inclusion of green that approaches statistical significance ($p = 0.057$).

An additional difference between the drawing and writing results was the presence of red in the middle of the trap in student work. In student drawings, there was a significant increase ($p = 0.000$) in the number of students ($n = 20$) who included red in the middle of the trap from pre-assessment to post-assessment. However, in the student writing, 26 students never wrote about red in the middle of the traps ($p = 1.000$).

Finally, a difference in the students' drawing and writing was related to the presence of the word trap as opposed to the presence of the structure. For example, 28 out of 31 students included the structure of the trap in both their pre- and post-assessment drawings ($p = 1.000$). When analysing student writing, we see a significant decrease in the inclusion of the words mouth ($p = 0.008$) and leaves ($p = 0.008$) from the pre-assessment to the post-assessment. Eight students included the word mouth in the pre-assessment writing and did not in the post-assessment writing, and eight students included the word leaf in the pre-assessment writing and did not in the post-assessment writing.

Discussion

Based on the findings, we conclude that, as a result of participating in a multimodal curricular unit focused on VFTs, (1) students increased their knowledge of VFT structure and function, (2) students showed evidence of synthesising information about VFTs from multiple modes included in the unit, and (3) students showed different types of understanding depending on the mode of assessment used.

Examining the drawings and writings produced by students at the beginning and end of the unit indicates that they increased their knowledge of VFT structure and function. Regardless of teacher-described reading level, most students increased the number of elements they included in their post-assessment drawings and writings as compared to their pre-assessments. In comparing the post-assessments to the pre-assessments regarding student knowledge of structures, students showed an increase in the inclusion of trigger hairs, red in the middle of the trap, nectar, and green traps. While knowledge of function was not indicated in their drawings, evidence of their understanding of function can be seen in their post-assessment writing as compared to the pre-assessment. Students showed a significant increase in the use of action verbs in their post-assessment writing. Twenty-seven out of 31 students wrote about a function in their post-assessment writing. Out of these 27 students, 22 correctly answered the function sentence stem with a function connected to capturing prey or meeting needs of the VFT. Additionally, we would argue that the increased inclusion of an insect in student drawings and writing in the post-assessments indicates an increased understanding of VFT function. The unique structures of the VFT are adaptations that enable the plant to acquire nutrients that are not available through the soil (Williams, 1980). By including insects in their drawing and writing, students are demonstrating that they understand the connection between the structures and their use in luring and/or capturing insect prey. Previous research has found that primary students tend to be focused on plant structure and rarely discuss functions (Kos & Jerman, 2015; Tunnicliffe, 2001; Tunnicliffe & Reiss, 2000); however, our findings demonstrate that a multimodal curricular unit focused on VFTs increased student knowledge of both structure and function of these unique wild plants.

A second conclusion drawn from the findings is that students synthesised information from multiple modes included in the unit: physical specimens, photographs, videos, text, and classroom discussion. We found a significant increase in student inclusion of trigger hairs and nectar in their writing, and red in the middle of the trap and insects in their drawings. These are features of VFT structure and function that are not easily observable in physical specimens in a classroom context; however, the importance of these features was reinforced through student observation of photographs and videos of VFT plant, classroom discussions, and through both shared reading led by the teacher and independent reading of text. In addition, students significantly decreased their use of terms such as 'mouth' and 'leaf' in their post-assessment writings, which may indicate that they were able to replace these terms with more accurate science vocabulary from text and/or classroom discussions of 'traps.' Multimodal curricular units provide students with information in multiple representations from which they can synthesise their understandings in meaningful ways (Prain & Tytler, 2012; Van Meter & Garner, 2005; Wallace, 2004). First graders were exposed to a variety of semiotic tools to represent

VFT structure and function from which they were able to construct their understanding through the epistemological activities of drawing and writing (Prain & Tytler, 2012). Though research has shown the benefits of multimodal learning in upper primary and secondary settings (Hubber et al., 2010; McDermott & Hand, 2013; Waldrip et al., 2010), our findings provide evidence that multimodal learning in science units is beneficial even in lower primary-grade levels.

Students were able to demonstrate different types of understanding of VFT structure and function in their drawings and writings; something here about the affordances of using drawing and writing with students together. We found that some elements were shown in both drawing and writing, while others were more frequently included in one mode of representation. While the age of students and subject area differ, our findings support Akaygun and Jones's (2014) assertion that students are better able to represent structural information through drawings as opposed to writing. In examining the mean number of elements included in student drawing as compared to writing, students were able to include more structures in their drawings, both in the pre-assessment (drawing: $x = 3.42$, $s = 1.29$; writing: $x = 2.03$, $s = 1.25$) and in the post-assessment (drawing: $x = 5.19$, $s = 1.30$; writing: $x = 3.52$, $s = 1.29$). Furthermore, our data reinforce the idea that teachers in primary grades who have students construct drawings in a science unit help students represent their ideas in a non-textual format (Chang, 2012; Danish & Enyedy, 2007). In providing students with a blank page on which to draw VFT both in the pre- and post-assessment, a lack of organisational structure on the page may have been enabling for this age group in representing their individual understanding of VFT structures (Danish & Saleh, 2014). While students were able to represent more knowledge of structures in their drawings, we found that writing provided an opportunity for students to exhibit their understanding of VFT function. As discussed above, student knowledge of VFT function was evident in the increased use of action verbs and in the number of students who correctly completed the function sentence stem in their post-assessment writing. The action verbs used by students in their post-assessment writing related to the movement of VFT structures to capture insects that were not represented in student drawing. Similar to Akaygun and Jones's (2014) finding that students were better able to show their understanding of the process of chemical equilibrium through writing, the first-grade students in this study were better able to represent their knowledge of the process of VFT luring and capturing prey through writing as opposed to drawing. Having young students use both drawing and writing as modes of representation of their scientific understandings, therefore, was beneficial as ways to compare information included across modes and compare their particular affordances.

Implications

Multimodal curricular units in science are beneficial for primary students. The first-grade students in our study showed evidence of knowledge gains of VFT structure and function after participating in a unit that combined the use of various semiotic tools (physical specimens, photographs, videos, text, and discussion), involved students in the epistemic practices of drawing and writing, and asked them to demonstrate their knowledge in multiple ways. We found that drawing and writing as epistemological activities at the culmination of unit enabled even lower primary-aged students to represent their scientific understandings. Similar to scaffolding described in Klein (2000) and Adoniou (2013), students were involved in discussions and modelling to support their writing process; however, no such support activities were included for drawing. Danish and Saleh (2014) found the amount and type of guidance provided for student drawings impacted the science information students were able to convey. While there are scientifically accepted conventions for representing action in drawings, students are unlikely to have knowledge of these conventions without explicit discussion with their teacher (Waldrip et al., 2010) and a discussion of these was not included in the instruction of this particular unit. These factors may have shaped the type of information that the first graders were able to provide in their drawing and writing.

Another limitation of this study is that we did not talk with students about their drawing and writing to find out if the understanding they were demonstrating accurately reflected their thinking, which is a key method when working with young children and their drawings (Cox, 2005; Einarsdottir et al., 2009). While we encouraged children to represent their understandings of the structures and functions of VFTs using both writing and drawing, a potential next step would be to include a discussion with students about their drawing during the end-of-unit assessment to understand what they are trying to represent and to find out what they feel they cannot represent in their drawing and writing.

Our findings support the use of drawing as an epistemic practice of science and as an epistemological activity for synthesis of understanding in addition to other forms of communication and assessment (Prain & Tytler, 2012). Early primary students are developing their initial writing skills, and therefore additional forms of assessment are needed to gauge their understanding of science content. Current research supports the use of drawings as a representational tool for assessment and learning in upper primary students (Hubber et al., 2010; Waldrip et al., 2010). Our study supports the potential of drawings as representational tools not only for assessment, but for constructing understanding in early primary students alongside a more traditional mode, such as writing. Like other researchers, however, we recognise the need for drawing as a scientific practice to be taught in order for students to maximise their use of this mode (Danish & Saleh, 2014; Van Meter & Garner, 2005). Therefore, further research should investigate methods and strategies to introduce scientific drawing with early primary students.

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