

Exploring the Impact of EFTs on Students' Understanding of Systems-Based Agricultural Processes

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Abstract

As the food system, from production to consumption, has increasingly become complex, the need for food literacy among American school-aged children has also increased. Teaching and learning interventions using inquiry-based learning (IBL) can be used to improve food literacy. The purpose of this study was to determine how an IBL approach paired with electronic field trips (EFTs) impacted students' ability to understand a systems-based process. The influence of the intervention was examined in a three-part EFT series with a focus on the tomato food system (growing, processing, and consumption) through teacher observational data and student-generated drawings. Teacher observations indicated more than 80% of students demonstrated measured IBL markers. The comparative assessment of students' pre- and post-series drawings showed an increase in students' knowledge of the tomato food system. Students retained and built on their pre-existing knowledge of the tomato system, integrating more complex concepts into their post-series drawings. Results substantiate the educational value of EFTs in developing students' understanding of food systems. We, therefore, recommend the combined use of EFTs and IBL in learning environments to inform complex system topics aimed at improving food and agricultural literacy among elementary school students.

Introduction

Most American adolescents lack knowledge regarding where their food comes from, how it is processed, and how it gets to their plate each day (Brandt et al., 2017; Hess & Trexler, 2011; Powell & Agnew, 2011). Food systems, the process from growth to consumption, have increasingly become more complex; so too has the need for improved food literacy in American adolescents increased. Food literacy is similar to agricultural literacy, and concentrates on the critical knowledge (information and understanding) of individuals regarding food and fiber systems (National Research Council, 1988; Truman et al., 2017). According to Cullen et al. (2015), food literacy is defined as the “ability of an individual to understand food in a way that they develop a positive relationship with it, including food skills and practices across the lifespan in order to navigate, engage, and participate within a complex food system” (p. 143). Food literacy can be understood through six domains: “skills and behaviors, food/health choices, culture, knowledge, emotions, and food systems” (Truman et al., 2017, p. 370).

Ultimately, the food literacy of adolescents will impact the future of food production systems and food economies through the preferences, choices, and behaviors of these future adults (Ares et al., 2024).

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Evidence shows that adolescents' eating habits can be improved by increasing their knowledge of nutrition and cooking skills (Brooks & Begley, 2014; Markow et al., 2012; Nelson et al., 2013). A systems-based approach allows adolescents to understand the broader context of a food system, while a focus on local systems supports sustainable agricultural practices (Rotz & Fraser, 2015), improves food security (Pearson et al., 2011), and strengthens local economies (Lyson & Welsh, 2005). Beyond classroom learning, field trips provide the opportunity to develop an understanding of food systems and improve food literacy. The purpose of this research was to determine how an inquiry-based learning (IBL) approach paired with electronic field trips impacted students' ability to understand a systems-based process found in food production.

Literature Review & Theoretical Framework

Electronic Field Trips

Field trips have long served as a way for adolescents to experience events outside their normal routine (Tuthill & Klemm, 2002) and serve as a critical way for students to connect classroom learning to the real world (Tal, 2001). However, integrating field trips into the school year can be a challenge to teachers, with reduced funding for trips, plus logistical issues of time, transportation, and academic testing (Adedokun et al., 2011; Parker et al., 2010; Stoddard, 2009). Electronic field trips (EFTs) present a low-or-no-cost alternative to traditional field trips and require less time away from the classroom (Tuthill & Klemm, 2002). Additionally, EFTs allow more than one classroom to participate at a time, greatly increasing their effectiveness in reaching students.

While traditional field trips connect formal learning to non-formal, EFTs blend the two, as they bring an out-of-school location into the formal classroom setting (Adedokun et al., 2012a; Adedokun et al., 2012b; Tuthill & Klemm, 2002; Loizzo et al., 2019). In recent years, EFTs have frequently been utilized to present a variety of science topics to students (Cassady et al., 2008; Loizzo et al., 2019; McLeod-Morin et al., 2020). Cassady et al. (2008) noted that EFTs were most successful when they incorporated student activities and teacher curriculum and provided access to pre-trip learning materials. EFTs offer students the opportunity to engage with professionals through a two-way communication system, and foster learning through inquiry (Cheng, 2022), a critical element of IBL.

Inquiry-Based Learning

IBL encourages the development of scientific thinking by providing students with opportunities to ask questions, develop hypotheses, reflect on their learning, and integrate that learning with their prior knowledge (National Research Council, 2005). Generally, IBL is associated with indirect instruction methods, but it can also work with direct instruction, especially for students unfamiliar with IBL. As students become more empowered through IBL, they move toward more indirect, student-led development, testing, and reviewing of their own hypotheses (Turner et al., 2017).

IBL is often used with learning environments research, as an environment must be conducive to this style of instruction. In reflecting on the development of her inquiry-driven elementary classroom, McGonigal (1999) noted that careful thought and action were required to foster scientific inquiry in young adolescents. Special attention was needed to develop curricula containing interesting materials and encouraging observation and discovery. Teachers must cultivate a classroom environment that provides opportunities for risk-taking, exploration, revision of thinking, and reflection.

McGonigal (1999) concluded that a classroom centered around IBL fosters shared interest and ownership of learning between a teacher and their students and develops a community of active learners. Similarly, Robinson and Aldridge (2023) found that female students interacting with an IBL mathematics

classroom had a positive relationship with their learning environment, subsequently increasing their enjoyment of and willingness to engage with the subject. A similar study examining IBL and virtual field trips found a higher increase in the post-test scores of students when compared to their initial skill level (Sriarunrasme et al., 2015).

Turner et al. (2017) developed an instrument to assess IBL in classroom settings by observing key elements of IBL, such as developing questions and hypotheses, asking questions, generating discussion, and reflecting on learning. The instrument is intended for researcher use in classroom observations of students and teachers. The IBL instrument reported on in this manuscript was adapted for teacher use. Teachers reported observed behaviors among their students before, during, and after EFTs. Their observations of IBL indicators provided insight into the student element of the study: student-generated drawings.

Drawing as Scientific Inquiry

In scientific learning, drawing has been utilized to improve students' observational skills, memory, and imagination (Steele, 1991; Stein & Power, 1996). Drawing invites students to engage in the inquiry process, develop their scientific understanding, and express their content knowledge, especially in younger students (Ainsworth, 2011; Schmeck et al., 2014). Drawing can facilitate student comprehension and learning for more complex content, such as systems-based processes (Van Meter & Garner, 2005). Young students have been found to enjoy learning through drawings (Lind, 1998), which appeals to the hands-on learning recommendations for preschool and elementary students, especially in regards to topics of science (Chang, 2012; Lind, 1998).

However, the successful use of student-generated drawings requires the opportunity for learners to reflect upon recently acquired information (Hall et al., 1997), compare it against reference knowledge, and receive feedback (Landin, 2011). For effective use of drawings in scientific learning, Smith et al. (2019) recommended that prompts clearly align with what knowledge is being assessed and encourage deeper probing.

In cases where students are reluctant to draw or are not confident in their drawing skills, Chang (2012) posits that an alternative treatment may be considered to ensure equality in knowledge assessment. Short answer responses, for example, characterized as one phrase to one paragraph, allow students to recall their knowledge, make scientific claims, and provide evidence to support these claims (Burrows et al. 2014; Sampson & Clark, 2008). Pairing a written response with drawings reveals underlying thoughts and encourages reflection (Campbell & Fulton, 2003).

As outlined above, drawings serve as a way for students to process information and generate a deeper understanding of a topic. However, drawings also offer a window to recognize what students are not learning and can serve as a tool to identify misconceptions (Dikmenli, 2015; Dove et al., 1999; Ehrlén, 2009; Köse, 2008).

Constructivist Learning Theory

This study was guided by the constructivist learning theory (Piaget, 1970). The theory posits that learners actively develop their understanding of knowledge by interacting with their environment rather than passively consuming instruction (McBrien & Brandt, 1997). Constructivism allows learners' autonomy and motivation, while teachers as facilitators guide students through the inquiry process (Doolittle & Camp, 2003). In this study, constructivism informed our perspective on students' knowledge construction as the theory supports student experiences and informs their ability to advance existing knowledge and establish new understanding (Applefield et al., 2000). The process of knowledge construction often takes time, and

it requires internalization and application of knowledge beyond the learning space (Schcolnik et al., 2006). Knowledge internalization is dependent on the student's level of involvement, the content, and the context of activities (Brown et al., 1989). These tenets align with the philosophy of agricultural education such that students are exposed to rich information in authentic settings (Parr & Edwards, 2004).

Constructivist learning is associated with an inquiry approach through various hands-on engagements (Applefield et al., 2000). IBL is a student-centered learning approach that promotes the creativity and cognitive engagement of students (Ragland & Karcher, 2023). Drawing the connection between constructivism and IBL highlights the role prior knowledge plays in learning, for instance, when individuals build new knowledge upon existing cognitive knowledge (Serafin et al., 2015). The significance of IBL rooted in the constructivist paradigm is that students develop critical thinking that becomes expanded through reflection and active hands-on activities while gaining an understanding of the scientific inquiry (Thoron & Myers, 2011). Several studies, in an attempt to assess the strength of the IBL, have found that students exposed to IBL have a greater achievement score than those exposed to the traditional mode of instruction (Thoron & Myers, 2011; Witt & Ulmer, 2010). The study by Skelton et al. (2018) assessed the impact of IBL on meeting grade-level expectations among middle school students. The study found a favorable influence of IBL and recommended that IBL processes be integrated to enhance classroom instruction. In a meta-analysis of inquiry-based approaches, Hattie (2009) found the effect of IBL was consistently stronger among elementary students than those of higher class levels.

IBL has long been a part of agricultural education, as its principles and elements have been integrated into project-based learning, problem-solving, and experiential learning in agricultural classrooms (Baker et al., 2012; Dyer & Osborne, 1996). Agricultural educators adopt IBL to enhance students' learning and increase motivation, based on their perception of students (Baldock et al., 2022). Thoron and Burlison (2014) found that students had a beneficial experience with IBL instruction, which also contributed to their favorable perception of agriculture. Similarly, in an introductory animal science class, IBL activities proved to increase students' motivation to seek out future engagement with the course material (Ragland & Karcher, 2023).

Purpose & Objectives

The purpose of this research was to determine how an IBL approach toward electronic field trips impacted students' ability to understand a systems-based process. We explored student learning through teacher observational data and student-generated drawings. The objectives of this study were to 1) *describe the teacher-observed IBL markers students demonstrated* and 2) *based on the observed markers, to investigate IBL deepened students' understanding of the tomato system through the analysis of their pre- and post-series drawings*.

Methods

This study utilized a two-part quantitative methodology to explore the impact of an inquiry-based learning experience on students' understanding of a systems-based process.

Intervention

Researchers worked with Shift-ology Communication, an Ohio-based public relations firm that specializes in coordinating and conducting virtual field trips, to develop and host the EFT series. As the company had primarily hosted livestock-focused EFTs in the past, tomatoes were selected to explore a new topic area and feature one of Ohio's primary vegetable crops. The three-part EFT series titled *From Seed to Fruit: Tomato Production in Ohio* was hosted in May of 2023. The EFTs were held on the same day once a week for three weeks during school hours, with each EFT lasting between 32 and 36 minutes. Each field

trip covered a different element of the tomato food system: growing, processing, and consumption. Table 1 describes the location, description, host, topics, and learning standards covered by each EFT.

Table 1

Description of EFTs

	EFT 1 (Growing)	EFT 2 (Processing)	EFT 3 (Consumption)
Location	Witten Farm Market	Hirzel Canning Company	Franklin County Extension
Company Description	Family-owned vegetable farm with greenhouse operations	Family-owned tomato processing facility	County extension office for OSU Extension
On-Screen Host	Owner/farmer	Owner	Nutritional specialist
On-Screen Location Description	Tomato greenhouse with tomato plants growing in rows	Truck receiving/offloading areas, tomato sorting and processing line, cooking and canning operations, shipping/transportation areas	Demonstration kitchen
Topics	Planting, harvesting, growth cycle, pollinators, irrigation	Cleaning, sorting, cooking, canning, transportation	Use of tomatoes in cooking, kitchen safety, food demonstration (salsa)
Learning Standard	Technology 3-5.ICT.1.a. Technology 3-5.ICT.2.a. Computer Science CS.HS.4.a.	Technology 3-5.ICT.3.b. Technology 3-5.ICT.3.c. Technology 3-5.DT.3.c.	Technology 3-5.ICT.1.a. Technology 3-5.ICT.2.b. Physical Education 3.3

The EFTs were targeted toward 3rd-5th grade classrooms in Ohio, though classrooms of other grades or locations were not restricted from participation. EFT advertising was sent to Shift-ology's list of science teachers between 3rd and 5th grade and posted on their website. Additionally, advertising was sent to OSU Extension and a list of homeschool co-ops in Ohio. The EFTs were free for all classrooms. Participants had the option to sign up for single EFTs, or the entire series and were provided instructions for watching the live broadcast. Due to the live nature, classrooms were able to interact with the broadcast by sending questions in real-time to be read by the EFT moderator. This format allowed teachers to facilitate an IBL process and receive the benefits of a field trip while also remaining in their familiar classroom setting.

Teachers who signed up for the series were provided five lesson plans, one for each EFT and an additional plan for the start and end of the series. The lesson plans were designed by an education expert to meet Ohio standards for 3rd to 5th grade. The plans incorporated IBL principles to facilitate student engagement in the EFTs. The pre-series lesson plan encouraged classrooms to develop questions for speakers to ask during the live sessions. After each EFT, the lesson plans included prompts to stimulate classroom discussions and encouraged students to compare what they learned with their original understanding of the tomato system. In addition, the consumption EFT (3) included a food demonstration. Instructions and an ingredient list were provided in the trip's lesson plans, thus encouraging classrooms to engage in the hands-on activity during the trip.

The EFTs were recorded, and the link was provided to all registrants so that they could watch the series at any time, albeit without the live, interactive component. Each EFT was hosted on Zoom and simultaneously livestreamed to YouTube. The growing EFT (1) is available at <https://bit.ly/4377V49>. The

processing EFT (2) is available at <https://bit.ly/3F0N36w>. The consumption EFT (3) is available at <https://bit.ly/4kbDEZ3>. The EFTs were part of a larger farm-to-school grant project funded by The Ohio State University's Connect and Collaborate Grant. Registration, live attendance, and YouTube views to date are reported in Table 2.

Table 2

<i>Recruitment, Attendance, and Views</i>							
	Registered			Live Attendance			Views
	Instructors	Unique Classrooms	Students	Instructors	Unique Classrooms	Students	
EFT 1	52	74	1257	21	27	480	145
EFT 2	52	68	1204	23	30	608	103
EFT 3	58	77	1354	24	31	581	98

Recruiting and Sampling

The research sample was drawn from teachers who had signed up their classroom for the EFT series. A total of 96 unique instructors registered for the EFT. Teachers were asked to opt-in to research activities: a pre-post questionnaire that assessed teacher IBL perceptions and the student drawing activity. 13 teachers completed the pre-series questionnaire, 10 teachers completed the post-series questionnaire, and 13 classrooms participated in the student drawing activity, resulting in 145 pre-series drawings and 160 post-series drawings.

Instruments

This quantitative study was conducted in two parts: a pre-post quantitative questionnaire for teachers and a quantitative content analysis of student-generated drawings. The pre-series questionnaire assessed teachers' perceptions of vegetable production and their demographics. Teachers who completed the pre-series questionnaire were shipped a food demonstration kit for their classroom to use during the third EFT, a cooking demonstration. Teachers who participated in the pre-series questionnaire were eligible to participate in the post-series questionnaire, which was adapted from Turner et al.'s (2017) classroom-observation assessment IBL instrument. In this study, teachers, instead of researchers, reported observed behaviors among their students before, during, and after EFT activities, including active participation, attentiveness, enthusiasm, and reflexiveness. Teachers who completed the post-series questionnaire were sent a \$25 gift card.

Teachers who participated in the pre-series questionnaire were also asked to conduct a pre- and post-series drawing activity with their classrooms. Students were asked to draw and describe the steps a tomato goes through to reach their school cafeteria before and after participating in the EFT series. In the first and last lesson plan, an activity sheet was included with a prompt designed to get students to think through a systems process: *How does tomato soup get to the cafeteria for your lunch? Draw the process, then explain your drawing below.* The sheet provided students with a large area for drawing and four lines to explain their drawing. Teachers who returned completed pre- and post-series drawings received an additional \$25 gift card. The pre-post drawing process allowed students the opportunity to reflect on their initial thoughts, identify their previous misconceptions, and recognize what they learned through the EFTs.

Data Analysis

The pre-post teacher questionnaires were analyzed using descriptive statistics. The pre-questionnaire was analyzed for descriptive values. The post-questionnaire asked teachers to report a percentage of students in which IBL behaviors were observed, based on teachers' perceptions of students demonstrating the IBL indicator. Means and standard deviations are reported for these percentages.

Student-generated drawings were treated as existing records, thus eliminating the need for parental assent and student consent, as approved by The Ohio State University's Institutional Review Board. The instructions for the pre-post drawing assessment with their classrooms required participating teachers to remove student information, such as names or schools, from the drawings prior to submitting them to the research team. Upon receipt, drawings were assigned a number and categorized based on the timing of completion (pre- or post-series). The pre-series and post-series drawings were analyzed collectively, and results were aggregated within the two categories without student or classroom matching or indication of which EFTs students attended.

The researchers performed a quantitative content analysis on the drawings and accompanying text. A codebook of key learning points was deductively developed from the topics presented during EFTs. For instance, when assessing growing EFT indicators, researchers looked for depictions of tomato plants, planting seeds, farmers, transportation, irrigation, etc. A total of 39 key points were identified, 15 in growing, 13 in processing, and 11 in consumption. Researchers evaluated each submission to determine if the submission contained each learning point through visual or written reference. To establish inter-coder reliability, all researchers coded the first 10% of pre- and post-series drawings and then compared the coding results. After two coder-training cycles, intercoder reliability was between the range of .685 - .980 for 35 of the 39 key learning points. This range is considered acceptable (Riffe et al., 2005; Krippendorff, 2004).

The researchers retrained on the remaining four variables and then were assigned a segment of the remaining drawings to code individually. A count was taken of the resulting data for each key learning point, classified by timing (pre-series or post-series) and style (drawing or text), which was divided by the total number of drawings assessed for the pre-series ($n = 145$) and post-series ($n = 160$) to understand frequency as a percentage of the total drawings. Post-series frequency percentages were subtracted from the pre-series frequencies to understand change as an increase or decrease in frequency. Inferential comparisons were unable to be completed due to the anonymous nature of the drawings and small counts in some variables.

In the two-part quantitative study, the data from the teachers' questionnaire is intended to provide insight into the trends and changes from the students' pre-series drawings to their post-series drawings.

Results

As noted above, 13 teachers participated in the pre-series questionnaire. All teachers identified as female ($n = 13$) with teaching experience ranging from 5 to 33 years. Class sizes ranged from 5 to 46 students for a total of 337 students. Participants mostly represented 4th grade ($n = 5$) and 5th grade ($n = 4$) classrooms. Most teachers ($n = 10$) had participated in 6 or fewer virtual field trips, including this series. When asked how often they taught agriculture in their classroom, most teachers indicated including agricultural curriculum approximately once a month ($n = 8$).

Describe the Teacher-Observed IBL Markers Students Demonstrated

In the post-series questionnaire, teachers were asked to report the percentage of their students demonstrating each IBL marker for each stage of the series. Ten teachers ($n = 10$) completed the post-series questionnaire.

Teachers were provided with lesson plans to use in their classrooms before each EFT. When participating in the planned lessons, teachers reported that 92% of students ($M = 92.2$, $SD = 9.041$) demonstrated an understanding of the lesson content, and 86% ($M = 85.5$, $SD = 17.704$) appeared to be mastering the lesson objectives. Most students were actively participating in ($M = 83.0$, $SD 23.195$) and paying attention to ($M = 81.50$, $SD 12.547$) the lessons. Pre-series IBL markers and their corresponding means and standard deviations are reported in Table 3.

Table 3

Percentage of Students Demonstrating IBL Markers During the Provided Pre-EFT Lesson Plans, as Reported By Teachers

	<i>n</i>	<i>M</i>	<i>SD</i>
Demonstrate understanding of pre-trip lesson content objective	10	92.20	9.041
Appear to be mastering pre-trip lesson objective(s)	8	85.50	17.704
Actively participating in pre-trip lessons	8	83.00	23.195
Paying attention to supplied pre-work	8	81.50	12.547
Enthusiastic about pre-trip lessons	8	77.88	23.467
Generate questions beyond primary pre-trip lesson objective(s)	8	64.63	33.645
Appear frustrated with pre-trip lessons*	5	7.80	14.805

Note. *n* represents the number of teachers reporting for each variable, not the total number of students. *M* and *SD* based on percentage of students reported by instructors.

*indicates a reverse-coded item

During the EFTs, teachers indicated 92% of students ($M = 92.00$, $SD = 9.592$) students demonstrated an understanding of the content objective. In addition, students were actively participating in ($M = 83.30$, $SD = 16.839$), paying attention to ($M = 82.10$, $SD = 16.839$), and enthusiastic about ($M = 81.60$, $SD = 17.84$) the trips. EFT IBL markers and their corresponding means and standard deviations are reported in Table 4.

Table 4

Percentage of Students Demonstrating IBL Markers During EFTs, as Reported By Teachers

	<i>n</i>	<i>M</i>	<i>SD</i>
Demonstrate understanding of EFT content objective	8	92.00	9.592
Actively participating in EFT	10	83.30	16.839
Paying attention to EFT	10	82.10	16.121
Enthusiastic about EFT	10	81.60	17.84

Note. *n* represents the number of teachers reporting for each variable, not the total number of students. *M* and *SD* based on percentage of students reported by instructors.

After the series was completed, teachers reported that 94% of students reflected on what they had learned from the EFTs ($M = 94.10$, $SD = 11.239$). The lesson plans encouraged students to create and test hypotheses. Teachers reported that 82% of students used prior knowledge to interpret the results of ($M = 82.67$, $SD = 16.485$) and engaged in evaluating ($M = 82.00$, $SD = 13.401$) their hypotheses. Eighty percent of students were able to identify previously held misconceptions at the conclusion of the series ($M = 80.20$, $SD = 24.697$). Post-series IBL markers and their corresponding means and standard deviations are reported in Table 5.

Table 5

Percentage of Students Demonstrating IBL Markers After EFTs, as Reported By Teachers

	<i>n</i>	<i>M</i>	<i>SD</i>
Reflected on what they learned	10	94.10	11.239
Use prior content knowledge to interpret results	9	82.67	16.485
Engage in evaluation of their hypotheses	6	82.00	13.401
Identify misconceptions	10	80.20	24.697

Note. *n* represents the number of teachers reporting for each variable, not the total number of students. *M* and *SD* based on percentage of students reported by instructors.

Investigate if IBL Deepened Students’ Understanding of the Tomato System Through the Analysis of Their Pre- and Post-Series Drawings.

Growing EFT

Prior to participation in the growing EFT, student drawings most commonly included “tomato plants” (drawing *n* = 66, 46%; writing *n* = 35, 24%), “transportation from the field” (drawing *n* = 40, 28%; writing *n* = 30, 21%), “farmer” (drawing *n* = 35, 24%; writing *n* = 14, 10%), and “handpicking” (drawing *n* = 30, 21%; writing *n* = 32, 22%). These elements generally increased in frequency in the post-trip drawings and writing, though both “tomato plants” and “farmer” were slightly less frequent in post-trip writings.

Several key points had a large frequency increase in both the drawings and writings from pre- to post-trip: “seeds” (drawing 13%, writing 13%), “greenhouse” (drawing 12%; writing 9%), “watering/irrigation/rain” (drawing 9%; writing 10%), and “transportation from field” (drawing 9%; writing 9%). Visual representations of tomato plants increased by 13% from pre- to post-trip, while “planting seeds/tomatoes” was more frequently mentioned in the post-trip writings (22%). Figure 1 depicts a pre-series drawing versus a post-series drawing with an emphasis on the growing element. All growing EFT key points, their frequencies, and the change from pre-series to post-series are reported in Table 6.

Figure 1

Pre- and Post-Series Student Drawings With an Emphasis on Growing

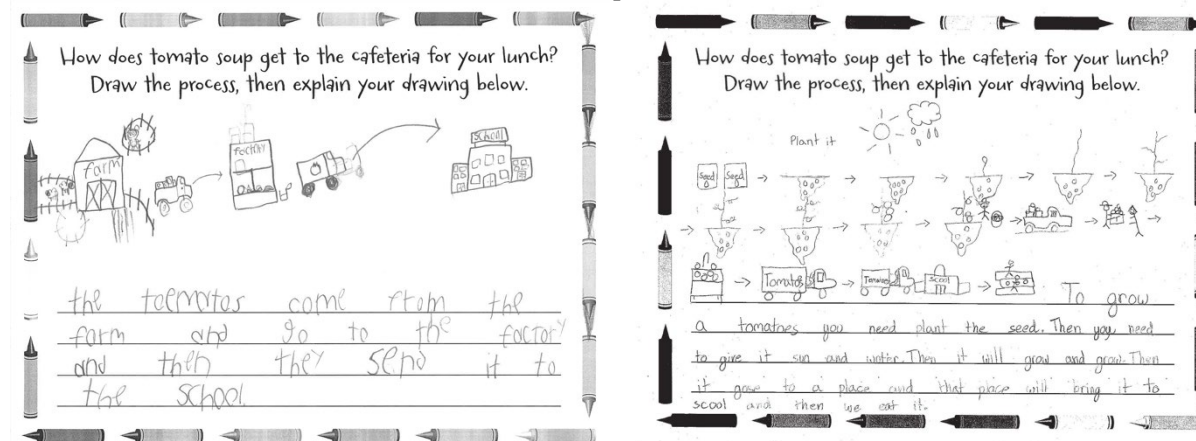


Table 6

Comparison of Key Points From the Growing EFT, as Depicted In Student Drawings And Writings, From the Pre-Series EFT Drawings (n=145) to the Post-Series Drawings (n=160)

	Drawing					Writing				
	Pre-series		Post-series		Change	Pre-series		Post-series		Change
	n	%	n	%		n	%	n	%	
Machine harvest	1	1	11	7	6	2	1	15	9	8
Watering/irrigation/rain	2	1	17	11	9	1	1	17	11	10
Greenhouse	4	3	23	14	12	0	0	14	9	9
Tomato blossoms	3	2	17	11	9	0	0	3	2	2
Composting	0	0	3	2	2	0	0	2	1	1
Seeds	18	12	41	26	13	11	8	33	21	13
Soil	15	10	31	19	9	6	4	5	3	-1
Handpicking	30	21	47	29	9	32	22	43	27	5
Farmer	35	24	51	32	8	14	10	13	8	-2
Transportation from field (crate/truck)	40	28	58	36	9	30	21	48	30	9
Tomato plants	66	46	94	59	13	35	24	31	19	-5
Planting seeds/tomatoes	11	8	14	9	1	11	8	47	29	22
Bees	0	0	1	1	1	0	0	0	0	0
Stakes/strings	2	1	2	1	0	0	0	0	0	0
Plastic Mulch	0	0	0	0	0	0	0	2	1	1

Note. Percentage has been rounded to the nearest whole number.

Processing EFT

Prior to participation in the processing EFT, student drawings most commonly included “transportation to schools/stores” (drawing $n = 47$, 32%; writing $n = 52$, 36%), “processing – crushing, juicing, cutting, squeezing” (drawing $n = 33$, 23%; writing $n = 22$, 40%), “filled cans” (drawing $n = 17$, 12%; writing $n = 18$, 12%), and “factory” (drawing $n = 15$, 10%; writing $n = 13$, 9%). These elements increased in frequency in the post-trip drawings and writings, except for “processing,” which decreased but was still represented in 14% of drawings.

Three key points had a large frequency increase in both the drawings and writings from pre- to post-trip: “washing tomatoes” (drawing 17%; writing 20%), “filled cans” (drawing 10%; writing 9%), and “sorting for quality, desirable fruit, color, size” (drawing 5%; writing 7%). Visual representations of conveyors increased by 5% from pre- to post-trip. Figure 2 depicts a pre-series drawing versus a post-series drawing with an emphasis on the processing element. All processing EFT key points, their frequencies, and the change from pre-series to post-series are reported in Table 7.

Figure 2

Pre- and Post-Series Student Drawings With an Emphasis on Processing

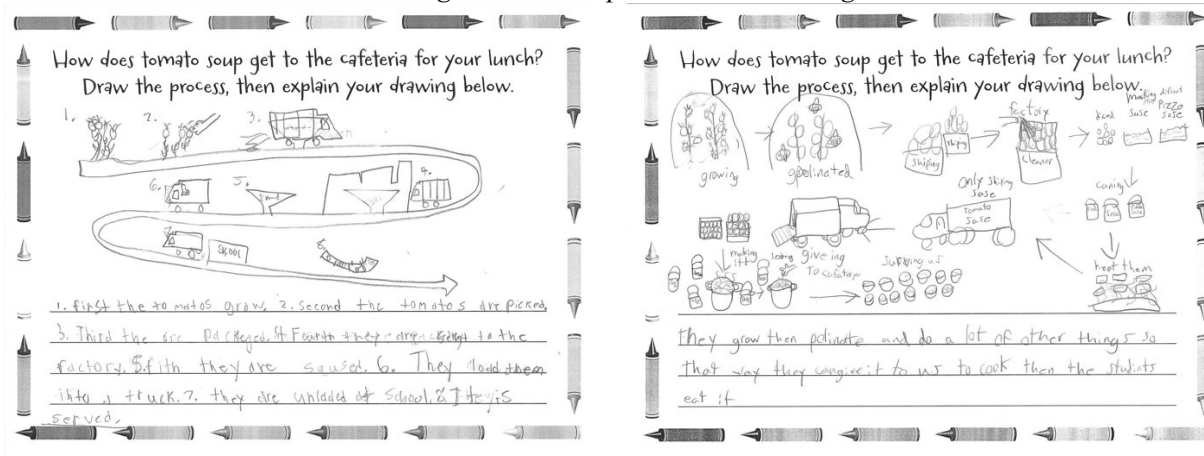


Table 7

Comparison of Key Points From the Processing EFT, as Depicted In Student Drawings And Writings, From the Pre-Series EFT Drawings (n=145) to the Post-Series Drawings (n=160)

	Drawing				Change	Writing				Change
	Pre-series		Post-series			Pre-series		Post-series		
	n	%	n	%		n	%	n	%	
Sorting for quality, desirable fruit, color, size	1	1	9	6	5	1	1	12	8	7
Washing tomatoes	5	3	33	21	17	5	3	37	23	20
Conveyors	2	1	11	7	5	1	1	2	1	1
Cooking/heating the can	0	0	5	3	3	0	0	7	4	4
Coating cans	0	0	4	3	3	0	0	2	1	1
Empty cans	2	1	6	4	2	1	1	2	1	1
Palletizing	2	1	5	3	2	1	1	3	2	1
Unloading tomatoes at processing plant	0	0	2	1	1	0	0	0	0	0
Filled cans	17	12	34	21	10	18	12	34	21	9
Factory	15	10	20	13	2	13	9	15	9	0
Transportation to schools/stores	47	32	53	33	1	52	36	62	39	3
Cover with lids/seal lids	1	1	1	1	0	1	1	2	1	1
Processing - crushing, juicing, cutting, squeezing	33	23	22	14	-9	40	28	34	21	-6

Note. Percentage has been rounded to the nearest whole number.

Consumption EFT

Prior to participation in the consumption EFT, student drawings most commonly included “school/school cafeteria” (drawing $n = 49$, 34%; writing $n = 57$, 39%), “preparing tomatoes – cutting, dicing, cooking” (drawing $n = 46$, 32%; writing $n = 47$, 32%), “people” (drawing $n = 41$, 28%; writing $n = 20$, 14%), “buying/transporting tomatoes from point of purchase to consumption” (drawing $n = 38$, 26%; writing $n = 38$, 26%), “tomato soup” (drawing $n = 32$, 22%; writing $n = 42$, 29%), and “non-school setting – home/kitchen” (drawing $n = 24$, 17%; writing $n = 8$, 6%).

Only one key point had a moderate frequency increase in both the drawings and writings from pre- to post-trip: “salsa” (drawing 4%; writing 5%). Visual representations of non-school settings increased by 3% from pre- to post-trip. Though many of the above key points decreased in frequency from pre-series drawings to post-series, they were still well-represented in the post-series drawings overall: “school/school cafeteria” (drawing $n = 46$, 29%; writing $n = 68$, 43%), “preparing tomatoes – cutting, dicing, cooking” (drawing $n = 33$, 21%; writing $n = 32$, 20%), “people” (drawing $n = 41$, 28%; writing $n = 20$, 14%), and “buying/transporting tomatoes from point of purchase to consumption” (drawing $n = 26$, 16%; writing $n = 22$, 14%). Figure 3 depicts a pre-series drawing versus a post-series drawing with an emphasis on the consumption element. All consumption EFT key points, their frequencies, and the change from pre-series to post-series are reported in Table 8.

Figure 3

Pre- And Post-Series Student Drawings With an Emphasis on Consumption

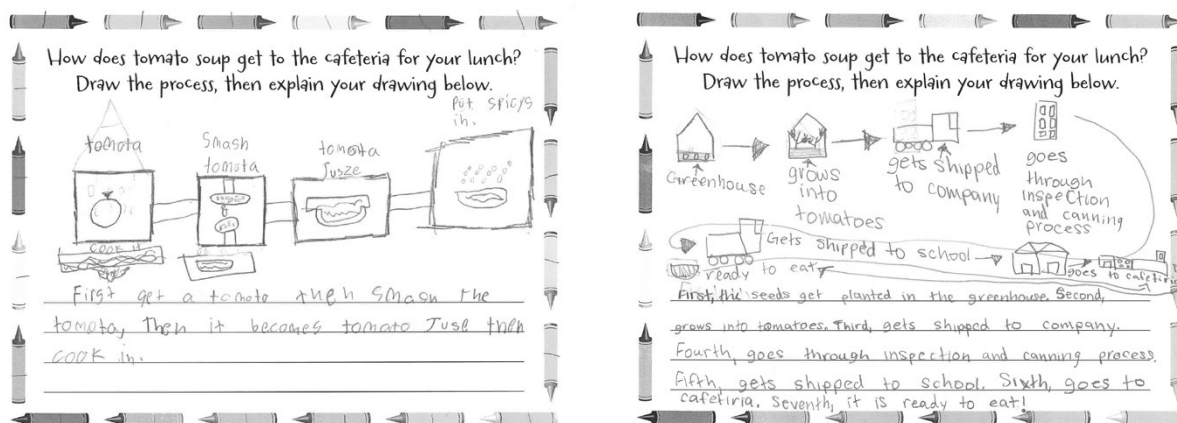


Table 8

Comparison of Key Points From the Consumption EFT, as Depicted In Student Drawings And Writings, From the Pre-Series EFT Drawings (n=145) to the Post-Series Drawings (n=160)

	Drawing					Writing				
	Pre-series		Post-series		Change	Pre-series		Post-series		Change
	n	%	n	%		n	%	n	%	
Salsa	2	1	9	6	4	2	1	10	6	5
Addition of other food products	8	6	11	7	1	10	7	10	6	-1
Non-school setting (home/kitchen)	24	17	32	20	3	8	6	9	6	0
People	41	28	46	29	0	20	14	20	13	-1
Washing hands/wearing gloves	0	0	1	1	1	1	1	0	0	-1
School/school cafeteria	49	34	46	29	-5	57	39	68	43	3
Eat	15	10	14	9	-2	26	18	25	16	-2
Preparing tomatoes - cutting, dicing, cooking	46	32	33	21	-11	47	32	32	20	-12
Other tomato-based foods	13	9	9	6	-3	9	6	6	4	-2
Buying/transporting tomatoes from point of purchase to consumption	38	26	25	16	-11	38	26	22	14	-12
Tomato soup	32	22	16	10	-12	42	29	14	9	-20

Note. Percentage has been rounded to the nearest whole number.

Discussion, Implications, and Recommendations

Electronic field trips have often been used to connect students with scientific topics (Cassady et al., 2008; Loizzo et al., 2019; McLeod-Morin et al., 2020) and inspire learning through inquiry (Cheng, 2022). Through IBL, students are encouraged to ask questions, develop hypotheses, reflect on their learning, and integrate that learning with their prior knowledge (National Research Council, 2005). By creating a collaborative, student-led environment, IBL builds a community of learners excited to engage in classroom subjects (McGonigal, 1999; Robinson & Aldridge, 2023).

Turner et al. (2018) indicated classrooms utilizing IBL were more successful when they engaged 80% of students in given markers. In the current study, teachers indicated more than 80% of students demonstrated almost all indicators of IBL measured. This finding confirms the work of Hattie (2009), which suggests strong effects of IBL among elementary-aged students. Students were interested and engaged in the EFTs, before, during, and after the trips. As a result, students understood the content with which they were engaging and were able to identify misconceptions, interpret results, and evaluate their hypotheses.

For younger students, such as the 4th and 5th graders who participated in this activity, drawing provided the opportunity to express their content knowledge and develop their scientific understanding (Ainsworth, 2011; Schmeck et. al, 2014). The associated short writing prompt allowed students to describe their drawings and provided greater insight to the underlying thought behind their models (Campbell & Fulton, 2003).

The drawing activity was designed in two parts to encourage IBL. The pre-drawing was intended to foster an environment of IBL by inspiring curiosity and excitement about the EFTs, encouraging question generation, and priming students to be observant during the trips (Steele, 1991; Stein & Power, 1996; Turner, 2018). The post-drawing focused on the reflection and misconception elements of IBL by providing an opportunity for students to depict their observations and process a complex food system that was represented over three trips (Ainsworth, 2011; Schmeck et al., 2014; Van Meter & Garner, 2005).

Prior to the EFTs, students expressed limited knowledge of the tomato food system, focusing on basic concepts related to tomato production such as “tomato plants,” “farmer,” “filled cans,” and “preparing tomatoes” in their pre-series drawings. However, this baseline knowledge offered students the foundation to advance their existing and establish a new understanding, consistent with constructivist learning theory (Applefield et al., 2000). These observed tomato food system elements and other frequent pre-trip indicators generally increased in frequency for the post-trip drawings and writings, indicating students generally retained and reinforced their beginning knowledge of the system.

However, there were a number of key points that had large frequency increases from pre- to post-series. These elements, including “machine harvest,” “greenhouse,” “sorting for quality,” and “conveyors,” represented more detailed, nuanced elements of the tomato food system. Paired with the retention of the introductory topics, the increase of more complex points indicates that students built on their prior knowledge to integrate additional elements of the tomato system. Thus, this finding reinforces the importance of the internalization and application process that occurs overtime and strengthens learning (Scholnik et al., 2006). We anticipate, based on the tenants of constructivism, that key point increases would have been smaller if all EFTs were completed on the same day and without the corresponding lesson plans.

While the data showed frequency increases for key points in growing and processing, consumption key points only increased slightly or decreased from pre- to post-series. We attribute this difference first to the prompt, which primed students to think about both “school cafeterias” and “tomato soup,” likely influencing their response. In addition, the consumption EFT focused on making salsa by adding ingredients to tomatoes, which likely moved students’ thinking toward these points. In addition, students’ prior knowledge likely played a part, as many pre-series drawings dedicated more space to the consumption element, which they would have the most familiarity with. In contrast, with exposure to more details on tomato growth and processing, post-series drawings had more space dedicated to these areas. The role of students existing knowledge and evidence of their expansion of knowledge is supported by constructivist learning theory and IBL (Applefield et al., 2000; Brown et al., 1989; McBrien & Brandt, 1997; Scholnik et al., 2006; Serafin et al., 2015).

In both pre- and post-series drawings, few key points were observed in abundance. However, it is important to recall the target age group of the series: children in 3rd to 5th grade, typically 8-11 years old. Though students may have only depicted a handful of key points, they demonstrated an increased understanding of the food system overall. This improvement reinforces the educational value of EFTs as described in previous literature in developing students’ understanding of systems, as well as food and agricultural literacy (Cassady et al., 2008; Loizzo et al., 2019; McLeod-Morin et al., 2020). Additionally, the findings expand the application of IBL and agricultural education (Baker et al., 2012; Dyer & Osborne, 1996) beyond the traditional agricultural education classroom and learning methods.

Results of this study are limited to teachers and students in Ohio who participated in the EFT series and its accompanying activities. This study is limited by the small sample size as well as the inability to directly compare pre- and post-series data for either the teachers or the student-generated drawings. Another notable limitation of this study is the large standard deviation observed in the teacher observational data. This high variability suggests that teachers varied greatly in their implementation of IBL, which may have

impacted students' learning. This study is also limited by who was solicited to participate in research, as teachers who regularly engage in virtual learning experiences likely have a more interactive classroom design. In addition, the evaluation of the drawings was challenging due to the age of the student participants, which sometimes resulted in incomprehensible pictures or writing.

This research offers valuable insights for those who create learning experiences for elementary-aged children. An interactive, reflective classroom format enables students to take control of and engage with their own learning. Instructors should incorporate elements of IBL into their program designs, emphasizing student-driven learning through question development and hypothesis testing. Sufficient time should also be integrated into programming to allow students to reflect on what they have learned and address how misconceptions have evolved. Although this study employed a three-series approach and observed small knowledge gains regarding the tomato food system from pre- to post-series, integration of IBL into a single event focused on one topic, rather than a system, may result in more significant learning about that topic.

Future research should match teacher observations with their classroom's drawings to better understand the connection between IBL markers and changes in drawings pre- to post-series. Direct comparison of individual student drawings would also assist in strengthening the results. The drawing activity could also be revised to better represent IBL markers. For instance, the pre-series drawing could ask students what they are curious about while the post-series activity could ask them what they learned and how it was different than what they thought. Furthermore, the learning environment could be enhanced by giving teachers a briefing of what to expect during the EFTs and providing them more mentorship and instruction regarding the facilitation of IBL during the EFTs. Examining teacher experiences with the EFT series and further understanding their classroom observations would also be of value.

Additionally, future research should explore strategies to increase the number of drawings returned, whether that's providing teachers with a large, pre-paid envelope for return mailing or a larger incentive for participating teachers. Direct administration of the drawing activity would also ensure participation and return in the research activity. For an increased understanding of IBL implementation, researchers should also plan to observe a classroom in person to measure IBL markers, though this would require a trade-off of participating classrooms and reach.

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