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# Collective Engagement in a Technologically Mediated Science Learning Experience: A Case Study in a Botanical Garden

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**Abstract:** This paper presents an interactional case study from *Tree Investigators*, a research study designed as a technologically mediated tour of an arboretum where children aged 7-11 collaboratively learn about the characteristic features of different types of trees. Throughout the tour, children are facilitated by a Naturalist and use mobile technology (e.g., iPads) to focus on specific characteristics of trees on their touch screens while observing the trees and discussing about them. This analysis focuses on a group activity where children use a mobile app to identify a *mystery tree*, analyzed through video-based Interaction Analysis. The findings reveal a collective engagement afforded by a coordinated interaction between sensory modes (verbal, gaze, touch, spatial) and mobile technologies (iPads, AR content). The purpose of this analysis is to help researchers and educators utilize the analytical concept of the *collective* when designing or examining mobile learning activities outside of school.

The *Tree Investigators* research and design project investigates science learning within technologically enhanced outdoor informal learning institutions (ILIs) such as nature centers and arboreta. *Tree Investigators* includes a field tour at an arboretum where families and children are facilitated by naturalists to collaboratively learn about the characteristic features of different types of trees. Throughout the tour activity, children are accompanied by their families and are encouraged to use mobile technology (e.g., iPads) to discuss the scientific characteristics of trees as they observe trees. The analysis in this paper focuses on the coordination of sensory observations, interactions, technology, and science content when children were facilitated to use a mobile application to identify an unknown tree, called the *mystery tree*. This paper contributes an account of collective engagement, coupled with learners' sensory interactions, as a theoretical tool that can aid in the research and design of mobile computing to support out-of-school learning in ILIs.

## Conceptual Framework

This paper focuses on interactions between learners, mobile computers, and an outdoor learning center to exemplify a collaborative educational design which includes learner-centered pedagogy relevant to learning outside of school. With this focus, our work draws on two theoretical literatures: *collective* engagement (Thomas & Brown, 2011) and learners' interactions with technologies. The structure of our mobile learning activity includes learner-centered, small group engagement facilitated by a Naturalist where learners work on authentic problems to acquire new scientific information as part of a visit to the Arboretum at Penn State.

The learners' activities occur within the context of emerging technologies, which present a potential for analyzing what Thomas and Brown (2011) call the *collective*, which is a highly collaborative problem solving system relying on the complex, real time coordination of various resources — including people, skills, technologies, and interactions. The concept of the *collective* relates to the framework of distributed intelligence (Pea, 1993, White & Pea, 2011) whereby intelligence is seen as spread across social and material resources. In the same vein, "collective intelligence" is enlisted amongst the eleven core social and educational skills for children in the emerging participatory culture of the future (MacArthur Foundation, 2006, p. 4). Also, various attempts at re-imagining education, such as the Centre for Educational Research and Innovation (e.g., 'Schooling for Tomorrow' and 'Future of Higher Education'), direct educators towards a future where learning will require cross-disciplinary expertise encompassing multiple ways of knowing. Concepts like distributed intelligence and the *collective* enable researchers to understand that these multiple ways of knowing do not reside within the individual; rather, knowing locates itself in the dynamics of coordinated interactions of human and technological resources. An important characteristic of the *collective* as emphasized by Thomas and Brown (2011) is that the collective is "defined by an active engagement with the process of learning" (p. 52) while "providing access to an increasing number of resources managed by a technological infrastructure" (p. 53) since it is "well designed to facilitate peer-to peer learning, their *raison d'être*" (p.53). We rephrase these characteristics as: (1) active engagement with the learning process and (2) accessing multiple human and technological resources.

It is important to note that collective engagement invokes the concept of multimodality or multiple semiotic modes (Hodge & Kress, 1988; Kress, 2005; Kress, et al., 2001; Lemke, 2002) from the field of social semiotics. Kress et al. (2001) explains multiple modes within learning "when learners actively engage with all modes as a complex activity in which speech or writing are involved among a number of modes" (Kress et al., 2001, p.1). The importance of multiple modes in learning specifically science literacy is furthered by Lemke

(2002) who asserts that all meaning resides in the integration of complex material systems that span across temporal, spatial scales which can be seen as semiotic resource systems—separable only analytically. One semiotic resource is digital technology (Baldry & Thibault, 2006) that combines and unfolds other semiotic resources in new and innovative ways (O'Halloran, 2009). Researchers (e.g., Mann & Reimann, 2007) also emphasize the role of mobile learning technologies as mediating tools—acting as a cultural intermediary between the learner and his or her social and physical environment. In keeping with this view, we understand that mobile technology serves as a semiotic resource for families' meaning making.

Studies (e.g., Kahr- Højland, 2011; Sung et al., 2010) where out-of-school learning activities utilized mobile technologies have recommendations that align with characteristics of the *collective*. Sung et al. (2010) in their museum-based study found that students using a mobile problem solving guide system fared well in terms of interactions and learning-related discussions. Kahr- Højland's (2011) findings from a science centre study favor a narrative-based exploratory design for meaningful technological scaffolding. However, both studies lament learners' disengagement with the exhibits, and a lack of deeper analysis, especially when utilizing technologies. They recommend a detail-oriented design that explicitly directs learner's attention to some specific aspect of the materiality (e.g., texture, actual size) on-site in order to engage learners in in-depth discussions and careful study of the exhibits, instead of a focus on just the technology (Hsi, 2003).

## Research Question

How do mobile computers interact with sensory semiotic modes to support collective engagement of learners while exploring trees in an ILI?

## Methodology

### Setting and Participants

The study is set at the Arboretum at Penn State, a botanical garden that displays trees from across the world. The Arboretum at Penn State is a 370-acre ILI; it features 35 acres of groomed gardens, a children's garden focusing on Pennsylvania natural history, and an old growth stand of hardwood trees with walking trails. This ILI offers an outdoor space that could be designed to enable a participatory, immersive science learning experience. This aligned with the *Tree Investigators*' intent to focus on informal spaces where families can enjoy and learn from in situ scientific phenomena related to trees.

Ten families were recruited for the *Tree Investigators*; they were members of a nature center close to the Arboretum. The families were strategically selected: (a) as heavy users of ILIs and (b) because of their affinity for outdoor experience of life sciences. Our strategic selection of ILI visitors is aligned to research practices commonly used in empirical museum studies (e.g., Allen, 2004; Leinhart, Crowley & Knutson, 2002).

The *Tree Investigators* project uses Augmented Reality (AR) to bring web-based media to a smart phone or tablet such as an iPad. In designing the mobile website (Zimmerman, Land, McClain, Mohney, Choi, & Salman, 2013), we aligned with recommendations for mobile computers on (a) the importance of personalization to the learners' agendas (Kearney, et al., 2012), (b) brief just-in-time interaction with the device, to facilitate learning through conversation (Hsi, 2003; Kahr-Højland, 2011), and (c) matching the learners' expectations of the experience to the affordances of the device (Looi, et al., 2010; Sung et al., 2010). After interacting with the mobile website, learners were presented with a cumulating task to identify a mystery tree.

### Data Collection Techniques

Data was collected in the Fall of 2011 with 10 families (25 participants) including 15 children aged 7 to 11. Data collection occurred on weekdays when the schools were closed for teacher professional development. The research team organized families in smaller groups, which were each facilitated by a Naturalist during the 60-minute tour for each group. Videos of each of the 5 field tours were recorded, resulting in 5 hours of recorded data. The video data were transcribed into approximately 150 single-spaced pages of text.

### Data Analysis Procedures

In accordance with our research question, a video-based Interaction Analysis was conducted (Derry et al., 2010; Heath & Hindmarsh, 2002; Jordan & Henderson, 1995) to explain the interaction between the children's sensory modes and mobile technological modes (e.g., apps & AR content) in identifying a mystery tree as a collective engagement enterprise. Interaction Analysis aligned with the research question as it seeks to "investigate human activities such as talk, nonverbal interaction and the use of artifacts and technologies identifying routine practices and problems and the resources for their solutions." (Derry et al., 2010, p.1). Also, interaction analysis is best suited to ethnographic approaches (Heath & Hindmarsh, 2002), and the video-recorded field tour of the *Tree Investigators* followed ethnographic methods. These analytical procedures allow for capturing the complexity of interaction in its various steps including: video review sessions, cannibalizing, transcription, selecting events, and extracting fragments; these are described below.

Data analysis involved reorganizing the video-based transcripts into multimodal transcripts (Kress et al., 2001), which included the descriptive dimensions of the sensory modes like gaze, speech, and body posture and positioning. Reorganizing the transcripts to highlight both verbal and nonverbal elements allowed the researchers to make analytical insights related to collective engagement. Both verbal and nonverbal aspects were recorded using time as an anchor. Another criterion of data reorganization was preserving the interactional sequence in which sensory modes appeared (e.g., if the action preceded the verbal or if the mobile app was being used in conjunction with a sensory mode such as talk or touch).

The criteria for recognizing instances as *events* according to [Jordan & Henderson \(1995\)](#) are “coherence in some manner” along with “official beginnings and ending” (p. 20). Heath, Knoblauch and Luff (2000) add an additional criterion that events allow for the “enabling retrieval of critical information” (p. 313). Using these principles, the learners’ engagement with the mystery tree task episodes each formed one event. The events selected for analysis in this paper were: (a) related to collective engagement around the mystery tree task episodes, which totaled approximately 100 minutes of video, and (b) focused on the video sections where the interaction between sensory and technological modes were visible. The segments were identified based on the problem solving event of recognizing six scientifically relevant tree features (i.e., branching patterns, leaves/needles [shape, arrangement, margin/edge], fruit elements [color], flowers [shape, color]); these six scientifically relevant tree identifiers were included on the *Tree Investigator* mobile website and app. The *US Trees* app was used during the mystery tree task which has an interface that presents the identifying features of trees to support identification. *US Trees* is designed so that the user sees multiple possible options for each feature and can select one option after observing that feature on a real, virtual tree or an image of the tree. The selected options are then configured as possible tree identities in the app’s database.

This paper presents one analysis of one mystery tree task event, within which seven segments are presented to explain the interaction between the learners’ sensory modes (e.g., gaze, touch, verbal, spatial) and the available mobile technologies (mobile app, AR content) in the process of collective engagement to identify a tree. The seven segments are those identifying features that are noticed by the group in this particular event; the seventh segment is where the results are discussed. Moreover, the order in which these segments appear reflects the participants’ learning agenda during their collective engagement.

## Data and Findings

From the analysis of the data, we found the two characteristics of the *collective* ([Thomas & Brown, 2011](#)) in the interactions of the children equipped with both sensory and mobile technological resources in the informal education design of the mystery tree activity. We first analyze the interactions within each of the seven segments while referring to the data transcripts. Next, we discuss the event as a whole, guided by the two characteristics of the collective: (1) active engagement with the learning process, and (2) accessing multiple human and technological resources.

The collective engagement event using the mobile computer began when the three children, Lydia (aged 8), Emmy (aged 8), and Greg (aged 11), were introduced to the *US Trees* app to identify a tree’s scientifically relevant features as a means to identify an unknown tree (i.e., mystery tree). The Naturalist only intervened where the children needed facilitation. In the first two segments (below), Greg expressed curiosity about the flower (line 867) whereby the Naturalist used the AR content to show a digital photograph of the springtime flower (lines 867-893) and fruit (lines 897-911), to the learners.

867. [00:39:17.21] Greg: How do you figure out the flower?  
868. Naturalist: Right So when you're ready for the flower, you can come over here- or the fruit-  
869. both the fruit and the flower I'm gonna have to show you using this special thing.  
870. Lydia: (walks over and sits down next to Naturalist & Greg where a laptop and AR tags  
871. are laying) This is what I think  
872. [00:39:33.23] Naturalist: Soo. (picks up large AR tag) For the flower- I'm- right now what  
873. I'm going to do is augment the flower and the fruit for you. And by augmenting I mean I'm  
874. gonna use a digital representation of, um, the fruit and the flower to show you so that  
875. you can- because right now (points up at tree), it's the fall and so we can't see those two  
876. features and so I have to show you using this.  
-----  
900. Naturalist: So there's the color of that fruit! (holding AR tag in front of laptop)  
901. [00:41:03.09] Lydia: (taps iPad screen) There!  
902. Naturalist: Did you get it? Everybody got it?  
903. Rachel: You got the fruit, Emmy?  
904. Emmy: Yeah, I think so.  
905. [00:41:08.14] Naturalist: Alright. Great. So let's see- I think we're all good with that. (shuts  
906. laptop lid) I'm going to shut this up so that it doesn't get- whatever, dirty (laughs)  
907. Lydia: And this right here! What about this right here? (point iPad screen towards Naturalist  
908. and pointing with finger at a place on the screen)

909. Naturalist: Right So that is the flower shape, do you think- which one of those three do you  
 910. think that flower looked like?
911. Lydia: (taps screen) Right here.

The third segment (below) includes a conflict that arose between the children due to different possible trees showing up as possible mystery tree solutions on the *US Trees* app, which meant that there was some confusion in identifying the tree's salient features. As a result, the Naturalist suggested the three children to "work together to see what we selected" (line 919) and guided them to look at the 'leaf shape' (line 920) in the fourth segment. The video transcript shows that the children reached a consensus about the leaf shape, which the Naturalist reinforced (lines 921-923). The fifth segment shows a transition towards the branching structure (lines 929-932). The children chose 'opposite' on the *US Trees* app after a sensory engagement with the tree on-site and after they confirmed this observation with each other. For example, Lydia, moved closer to Emmy to look at her iPad screen and asked "What did you do?" (line 928), Figure 1. They touched and unfolded the leaves to observe and feel the branching pattern as shown in Figure 2. Even before the Naturalist asked them to pull down a "branch with leaves to take a closer look" (lines 923-924), Figure 3 shows the children attended to the branching structure by moving closer to the tree, by holding their gaze on the leaf pattern.

919. Naturalist: //let's all sort of work together to see what we selected (walks to and stands by tree).
920. [00:41:54.16] Naturalist: Let's look first at the leaf shape (3 youth gather around tree with  
 921. Naturalist). What did, um, what did- let's see (leans over to look at Greg's iPad screen). Okay!
922. Lydia: Right here? (Naturalist looks at Emmy's screen then Lydia's)
923. Naturalist: Uh huh. Yeah! I think that I think yer- hittin' the nail right on the head (pulls  
 924. down branch with leaves for youth to take a closer look), cuz if you kind of unfold it, it  
 925. looks- it looks like that one! (points at Lydia's screen)
926. Lydia: Mm hmm!
927. [00:42:13.15] Naturalist: I think that's right, okay!
928. Lydia: (to Emmy) What did you do? (leans over to look at Emmy's screen)
929. Naturalist: Soo. (looks at Greg's screen) And everyone picked the opposite branch- yeah!  
 930. Wow! Good job you guys! Okay, so, so you can see here that it is in fact opposite branching.  
 931. (holding bare branch out and pointing towards the node) those two branches came right  
 932. out of the same...point right there. What's the next one? (leans over to look at Emmy's  
 933. screen) What's the next one?
934. [00:42:33.02] Lydia: Over here?



Figure 1



Figure 2



Figure 3

Greg, Lydia, and Emmy used the *US Trees* app on the iPads together to support their observation and identification practices. Once the children verbalized their identification, the Naturalist also pointed at the trees' nodes to draw attention to the 3-dimensional, actual tree specimen. Here, the learners coordinated their interactions between the sensory modes (i.e., touch, observation) and the mobile technology, as they moved back and forth between them. The learners' sensory experience involved gaze, gesture, touch, and talk, which helped the children to identify and confirm the branching structure. The mobile app presented the children with specific options of branching structure, which in turn focused their attention on the scientific aspects of the mystery tree. The constraint of the app channeled their noticings (Kellah, 2010; Yew & Schmidt, 2012) to the scientific knowledge that is relevant in this learning moment—in keeping with mobile technology pedagogy that enables domain-specific thinking strategies and knowledge. The three children interacted with the dynamic screen that empowered them to navigate at their own pace and interest (Thomas & Brown, 2011) and also gave them the relevant results at the end of their engagement. This app's process of dynamic assessment differs from

picking identity markers on the static paper (as in a book) and is an important learner-centered attribute of a mobile computing environment for ILIs.

The sixth segment (below) began with confusion about the leaf margin (i.e., the texture of the edge of the leaf). Unlike the fifth segment above where there was a consensus about the branching structure as ‘opposite’, two of the three children, Emmy and Lydia, were confused about the ‘look’ of the leaf margin. Since the field tour is happening during autumn, the older autumn leaves have a different shape and texture than younger summer leaves, which the *US Trees* app featured. The children’s sensory experience told them that the leaves were “kind of bumpy” (line 936) and the children confirmed their observation by alternating between feeling the leaves and rereading the options on the mobile app. The Naturalist encouraged their coordination of these sensory and technological modes, and she only confirmed Greg’s selection (line 939) when he approached her to show that his *US Trees* identity “match” (line 938). The Naturalist knew that the 3-dimensional on-site leaf had a time restriction that called for manipulation of a fourth dimension (i.e., time of year). She directed the two confused children to consider a different ‘look’ of the older autumn leaves when she said that “it’s gotten crinkly and they are not as green anymore” (line 944). She attended to this instance, connecting the ‘now look’ of the autumn leaves with the ‘before look’ of the summer leaves. She said: “I think it’s crinkled up and so it looks like there’s a- there’s a tooth to it but I actually think that it’s probably smooth when the leaves- actually I can augment that too” (line 946). At this point the augmented image of the leaf is shown to the children so that they have a technologically accessed experience of the summer leaf.

936. Emmy: I think it's kind of bumpy (reaches up to touch a leaf on the tree)

937. Naturalist: You think it's kind of bumpy..

938. Greg: I have one match (tilts iPad screen towards LRM)

939. [00:42:43.13] Naturalist: Ahh! I think (smiles and nods at Greg) you might be on the right  
940. track//

941. Lydia: // It's kinda.. (touching a leaf)

942. [00:42:48.24] Naturalist: You know what? I think that, it's actually pretty smooth. I know- you  
943. guys do have a very sharp eye looking at that, because it does, a little bit, because it's gotten  
944. crinkly, and they're not as green anymore, I think it's crinkled up and so it looks like there's  
945. a- there's a tooth to it, but I actually think that it's probably smooth when the leaves-  
946. actually, I can augment that, too. (Rachel laughs off camera)

947. [00:43:12.07] Naturalist: Lemme show you the green leaves (walks back to laptop on ground),  
948. so we can- you don't have to take my word for it.

949. Rachel: It's a little bit harder when they're old and die.

950. Naturalist: Exactly (walks back to group carrying bag with AR tags)

951. [00:43:25.23] Naturalist: (opens laptop lid) Alright.

952. [00:43:42.02] Naturalist: Heloooo? (moving AR tag around in front of laptop).

953. Rachel: oohh.

954. [00:43:50.05] Naturalist: So, what do you think?

955. Lydia: I'm riiight. (taps iPad screen)

956. Naturalist: Oop!

957. Lydia: (sits up and looks at LRM) This.

958. [00:43:55.11] Naturalist: (singing) Technology. There we go.

959. [00:43:58.14] Naturalist: So whaddya think? Greg, what did you pick?

960. Greg: I picked oval.

The transitions in the above segments illustrate how mobile technology afforded a rich layering of realities, by varying time. The support in coordinating sensory and technological modes and using augmented reality to show variation over time, all contributed towards the collective engagement at the Arboretum. Particularly, in the seventh segment (lines 947-960), the use of AR, coupled with on-site observations and information from the app where the children themselves compare and self-assess their own identification as when Lydia exclaims “I’m riiight” (line 955) and Greg identifies the leaf shape as “oval” (line 960).

## Discussion

The discussion section is organized by the two defining characteristics of the *collective* (Thomas & Brown, 2011) to examine the interaction between mobile technologies and sensory semiotic modes to enable collective engagement of learners within an informal education design. We focus on two key areas of theory: (1) active engagement with the learning process and (2) accessing multiple human and technological resources.

### Active engagement with the learning process

The collective engagement of the three learners meant that they each took on an active role as the problem of identifying the mystery tree unfolded naturally (Kellah, 2010). The learners' interactions in the mystery tree activity reflect the individuals' learning agendas, which were encouraged by the learner-centered design of the integration of the Naturalist's pedagogy with the content from the mobile computing environment. Each learner accessed the sensory and technological semiotic resources. Sometimes the children worked individually while next confirmed with their group members (line 928) while other times, they attended to their group members by looking at what they were doing but picked their own option without confirmation from the peers (line 938). Throughout the activity, each learner exhibited an active engagement not only in identifying the mystery tree, rather in making sense of the identification problem by "riddling one's way through the mystery" (Thomas & Brown, 2010: p.9). This multimodal, collective sense making was seen when Emmy and Lydia were confused about the 'look' of the autumn leaf margin calling it "kind of bumpy" (line 936). They did not confirm the *US Trees* selection of the leaf margin until they were sure—by comparing the feel of the leaves to the options on the *US Trees* mobile app. The three children also involved the Naturalist in facilitating their thinking about this particular tree's feature. Incorporating supports from the adults on-site showed how learners engaged actively by utilizing all available resources to identify the mystery tree according to their personal learning agenda, which Thomas and Brown (2010) refer to as tinkering. Within the design of the activity, the Naturalist acted as a facilitator guiding them with their thinking process by her talk or by introducing AR content as technological semiotic resources (lines 942-946). This tinkering support becomes most visible when Greg expressed curiosity about the flower (line 867) since the tree had no flowers as it was autumn; here, the Naturalist used the AR content to access a digital photograph of the springtime flower (lines 867-876) and fruit (lines 900-911).

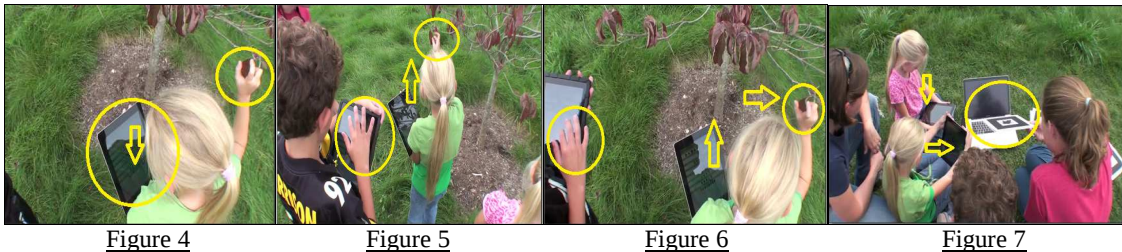
Moreover, the learners' active engagement was afforded by the structure of the mystery tree activity which takes a manageable form as it presented (yet limited) the available identifying features: branching patterns, leaves/needles (shape, arrangement, margin), fruit elements (color), flowers (shape, color) by means of the mobile app. Also, the repeated use of the same six features across modes supported the learners' sense-making since the children had already encountered these ideas in the earlier part of the Arboretum. Here, the technology afforded by the *US Trees* app aids in structuring the problem such that learners could access it in its composite and manageable parts that were linked to the children's prior knowledge. In keeping with recommendations (Kahr- Højland, 2011; Sung et al., 2010) that utilized mobile technologies in engaging activities, this channeling directed the learners' attention to specific features of the tree's materiality (e.g., leaf texture, color, shape.) so as to afford both engagement with and identification of the tree. Also, this repeated six feature structure functioned as a pedagogical tool whereby one iPad screen became the reference point for all participants (including the Naturalist) when converging together from where they depart into their own process of mystery-solving. Interestingly, this occurred at points of transition from one tree feature to the next— example: line 934 when Lydia asked: "over here?" and all attended to her iPad screen. This was in response to the Naturalist's directive of: "So, what's the next one?" (line 933) after they identified the branching pattern.

### Accessing multiple human and technological resources

The interaction between the available semiotic resources at the Arboretum allowed the three learners and the Naturalist to move back and forth between the sensory modes and technological modes. Throughout the learners' participation in solving the tree identification mystery, they do not appear to be conscious of the resources used in their collective engagement—especially their reliance on their own sensory modes when observing the trees. This overlooking of their (learners) sensory modes was also revealed in the post-tour interviews where when the children reflected on their experiences mentioned only the device as the tool helping them identify the mystery tree. For example, one boy reported that "I could never figure that out without looking all around that app on the iPad". Across all the learners, the children only noticed the role of technological modes in this activity. Lemke (2002) asserts that we never make meaning with only the resources of one semiotic system and we glide through the various semiotic systems in "relatively automated ways" (p.2) and this study reaffirms his claim that learners use various systems but perhaps without notice. Figures 4-7 above capture this pattern: the children first looked up the features on the app [see gaze onscreen, Figure 4], then they moved closer to the tree to look at a particular feature [see spatial move and gaze on on-site tree, Figure 4 & Figure 5], next they looked at the app options [see gaze onscreen, Figure 5] followed by touching and feeling that feature on the tree specimen multiple times at the Arboretum. When the children were confused about the leaf margin, each child not only touched one leaf multiple times but the children also touched and

observed multiple leaves on the tree for confirmation [i.e., touching concreteness and confirmation through sensory modes in Figure 6]. After this sensory confirmation from the leaves at the Arboretum, the children picked one option on the app [i.e., technological mode/app]. This process of engagement followed further confirming and getting to know what their peers have selected [see Figure 1] as illustrated when the children who were not sharing an iPad were seen to go to at least confirm and check their selection such as in line 928 when Lydia asked Emmy; “what did you do?” This confirming of specimens on-site and on others’ app choices was a more frequent move when a tree’s identifying features had a seasonal or time restriction (e.g., deciduous leaves, flowers, fruits).

Kress’s (2005, 2001) and Lemke’s (2002) perspectives explain these children’s engagement patterns as the inter-semiotic processes through which semiotic choices integrate to create meaning wherein the learner is empowered to make choices of which semiotic mode to use. The children also approached the Naturalist who used augmented reality (AR) to bring certain tree features to the children to technologically enhance the learning experience [i.e., technological mode/AR, see Figure 7]. The AR materials brought a digital ‘summer time’ to the Arboretum to be superimposed on the ‘autumn time’. Bringing together multiple seasons allowed for a complete identification of the mystery tree. In summary, throughout their experience at the Arboretum we have shown that these three children moved smoothly back and forth from sensory to technological modes to access needed information to identify the tree. In the context of this study’s findings, we posit this as learner’s choice of representational modes within the framework of the collective engagement.



## Conclusion

This exploratory study analyzed the interactions between various semiotic resources in the context of an informal educational project at the Arboretum at Penn State. It shows how learners move across resources and modes to develop their own paths towards collectively identifying a mystery tree. The collective (Thomas & Brown, 2011; 2010) was much more than just three children working together; it included the children making decisions about what was included in that collective (i.e., which resources and how to use them) while tinkering through the problem. Our findings, guided by the defining characteristics of the ‘collective’, include learners’ active engagement in utilizing human and technological resources. Our interaction analysis of modal transitions revealed the visible paths and choices of semiotic resources that these three learners picked to solve the mystery tree problem. Technological resources used in the study came across as powerful semiotic modes that afforded problem analysis (e.g., the interface of mobile app attending to focused features and the rich layering of realities afforded by the AR content). This study adds to our understanding of mobile technologies used as a learning tool within the context of informal science education when analyzed as a collective, learners take control of their own learning paths as they coordinated interaction between sensory modes (e.g., verbal, gaze, touch, spatial) and mobile technologies (e.g., iPads, AR).

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