Engaging Children with Nature through Environmental HCI

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ABSTRACT
Children do not experience nature as much as in past generations. Indoor technology use has been reported as the main competitor to playing outside. However, technology can also be used to encourage children to get outside and interact with the natural environment. This paper examined literature and known projects in Human-Computer Interaction (HCI) and related fields that aim to facilitate children's interaction with the natural world through technology. A thematic analysis was then undertaken in order to identify the different approaches to connecting children with nature through technology. We identified three major types of technology use, *instructional*, *exploratory* and *contributory*: (1) Instructional technology to enhance and enable structured science curriculum activities in outdoor environments; (2) Exploratory technology to encourage children to explore outdoors in nature; (3) Contributory technology to engage children in contributing to citizen science activities. We discuss ways to deepen and extend the scope of HCI research for environment, in order to entice and engage children to care about the physical environment and nature on its own terms, developing lasting connections to and knowledge about their natural environment.

Author Keywords
Children, natural environment, mobile and ubiquitous technology, augmented reality, sustainable HCI

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Many benefits can be enjoyed from exposure to nature. Louv (2005) in his most prominent book *Last Child in the Woods: Saving Children from Nature-Deficit Disorder* claimed that children who play in nature are healthier and more balanced. Hanscom (2016) in *Balance and Barefoot* shows how outdoor play and the unrestricted freedom of movement are crucial to children's cognitive and physical development and growth, helping children to grow into healthy, balanced, and resilient adults. A number of studies also show that experience and contact with nature during childhood influences pro-environmental behaviour as an adult (Arnold, Cohen & Warner, 2009; Chawla, 1999; Hinds & Sparks, 2008; Palmer, 1993; Palmer & Suggate, 1996; Wells & Lekies, 2006).

Conversely, lack of time spent in nature can lead to mental and physical health issues such as Attention Deficit Disorder (ADD), obesity, myopia, and depression (Cleland et al., 2008; CNN 2011; Fereira et al., 2006; Louv, 2005). While time spent in nature commonly leads to appreciation, respect and a sense of responsibility to protect the natural environment, non-exposure can lead to a lack of empathy which might threaten the environment and its sustainability in the future.

There are concerns that children do not experience nature as much as past generations, especially in urbanized parts of the world (Louv, 2005). Studies in the US (Clements, 2004) show that children spent less time playing outside and interacting with nature when compared to their parents' childhood. Natural England (2009) and Planet Ark (2011) reports show the same tendency for British and Australian children respectively.

One of the main causes of this trend, as also highlighted by Clements (2004); Louv (2005); Pergams and Zaradic (2006); and Singer et al (2009); is the increased use of technology indoors, such as watching television, playing video games and surfing the world wide web. Children's experience of nature has become more and more mediated by media (in particular television and video), creating an illusion that nature is somewhat exotic, exciting and in far-away places that they will never experience (White, 2004). Other causes include but are not limited to parent's safety concerns, loss of or limited access to natural surrounds, and increasing school time and homework. There is a growing confidence that technology can also play a role in enhancing children's experiences in and their connectivity to nature, through mobile and ubiquitous technologies.

In this paper we examined literature and known projects in the field of human-computer interaction that aim to facilitate children's interaction with natural world. We used a systematic approach to searching for literature. From this search we identified the different approaches taken to connect children with nature through technology, as well as noting the method and tool used. Based on our findings we also discuss the potential gaps and future directions to be considered by HCI research.

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METHODOLOGY

Our literature search began by searching the ACM Digital Library (ACM DL) using the keywords "sustainable HCI", "environmental HCI", and "environmental education". Every paper returned was examined from its abstract to see if it discussed the use of technology to connect children to nature or the outdoor environment. If so, we included it to our corpus. We also checked references of all papers included in the corpus, adding any of those papers that also fit the aforementioned selection criteria. We then extended our search by looking up other research outside the ACM database using the google scholar search engine. Only 18 papers were found that fit the criteria, 14 were found in the ACM DL and 4 were from other sources such as *Journal of Mathematics and Science Teaching*, and *Journal of Educational Technology and Society*. This reflects that HCI research attention to this area is still limited.

In addition, we also reviewed a number of mobile applications and projects on the World Wide Web that can encourage children to interact with nature.

The next step was to conduct thematic analysis on the papers and distil the different approaches taken as well as the particular methods and tools used. Our findings are presented below:

FINDINGS

We identified three major types of technology use in the effort to connect children to nature:

(1) *Instructional* technology - mobile and ubiquitous technologies enhance and enable structured science curriculum activities outdoors and on field trips;

(2) *Exploratory* technology - encourages children to explore outdoors in nature in a playful manner, using hide and seek and mission based apps that utilise GPS and mobile phones;

(3) *Contributory* technology - engages children in contributing to citizen science activities. They become participants in a community of practice, contributing to real world problems and apprenticing as scientists, although sometimes in quite limited ways.

In some cases more than one theme applied. The themes are described below.

Instructional technology to facilitate learning of science and nature curricula in outdoor environments

Using technology to extend the learning space beyond the classroom is thought to encourage more self-directed learning and potentially improve learning outcomes. We identified several technologies used to enhance science curricula including ubiquitous and mobile devices, digital cameras and acoustic devices.

Ubiquitous and mobile technologies enable anyone to engage in "anywhere and anytime" learning (Yahya *et al.*, 2010; Liu *et al.*, 2009). They can be used to augment ongoing activities, such as exploring outdoors, by enabling users to move back and forth between the physical environment and a variety of digital resources and representations (Rogers *et al.,* 2010). Such technologies are commonly used in digitally enhanced field trips (Grant, 1993; Liu *et al.,* 2009; Meek *et al.,* 2013; Rieger & Gay, 1997; Rogers *et al*., 2004).

The Ambient Wood project designed a digitally enhanced field trip for students using such a digital augmentation approach (Rogers *et al.,* 2004). Situated in a woodland, while they were exploring the surrounding environment, students interacted with devices that would let them read environmental data, hear ambient sounds and watch videos relating to biological processes in the wood that normally could not be heard or seen, as well as receive images and audio information triggered in particular locations. The intention was that students could intermittently switch their attention between experiencing the physical world and reflecting on knowledge of ecological process that would normally be unseen. Unlike traditional field trips, the Ambient Wood was designed to be much less structured aiming to promote student-initiated scientific enquiry, having some *exploratory* characteristics.

Similarly, Liu *et al.* (2009) conducted experiments to engage students in outdoor natural science learning by applying immersive ubiquitous technology. They utilized radio frequency identification (RFID) sensors, augmented reality (AR), and internet, to improve learning experiences for students in museum-like learning experiences. They divided student participants into a control group and experimental group and found that the experimental group, by using the technology, achieved significantly more learning than the control group did. Similar results were also found by Ohasi *et al.* (2008) and Suzuki *et al*., (2009) who used mobile technology to provide enhanced learning experiences in a zoo.

Another project utilizing mobile technology to engage children with scientific exploration in natural environments is the Lillypad project (Rogers *et al*., 2010) which had *instructional* and *contributory* characteristics. Students, teamed with environmental scientists, were involved in a project to monitor the ecological restoration of urban riverbanks. They participated in conducting observation, collection and recording of data that would contribute to determining the best practice of forest restoration. Students learned how to make measurements and participate in data analysis with the scientists to make sense of the changes observed.

Other digital forms used to facilitate learning are by using photograph and sound. Use of digital photography by students to study the health of a local stream ecosystem was investigated by Rivet and Schneider (2004). Students took photos of the stream environment and discussed what they found along it, including garbage, man-made constructions, plants, stream flow, etc. The study concluded that digital photography could extend student's abilities at scientific inquiry in environmental contexts. It was also found that students' desire to participate and their sense of ownership towards the local stream increased.

Several smartphone-based applications have been developed revolving around the use of digital photography to facilitate learning about the natural environment. The *Leafsnap* app uses visual recognition software to help users identify tree species from photographs of their leaves. With *Leafsnap*, children can learn about different types of plants while on a nature walk. School children enjoyed comparing specimens they found with those stored in the

electronic database, as well as using higher-level thinking skills to identify plants (Cooper, 2013; leafsnap.com).

Apps like *Audubon Birds of North America* and *Merlin Bird ID,* (audubon.org/apps; *merlin.allaboutbirds.org/*), provide electronic field guides that include high quality pictures, detailed descriptions and calls of birds. Both utilize millions of user-submitted bird observations obtained from the eBird citizen-science project.

Researchers have been using soundscapes to investigate biodiversity and sound characteristic in nature (Pijanowski et al., 2011) and some have shown that it can facilitate children to learn about the natural environment. Ohasi and Arisawa (2006) designed Nature Talk, a mobile learning application that can record sound data coupled with geo-location information, while exploring in nature. These are uploaded to a virtual sound map that can be access by other users. YELLs (Your Ecosystem Listening Labs) is an educational program using soundscape ecology that can be conducted in any informal learning setting such as summer camps, in museums or city parks. YELLs are set up as games, structured listening exercises, and research projects (centerforglobalsoundscapes.org).

Most technologies identified were developed to be used in in structured ways fitting within curricula and instructional contexts. Technology was often used to enhance existing field trips or other school-related activities.

Exploratory technology to motivate interaction with outdoor environment

With the recent rise of the Pokémon Go game app, a location-based augmented reality game, the role of mobile-apps in encouraging people to get outside, walk around and explore their outdoor environment has become more apparent. It uses GPS technology on mobile phones to locate and capture virtual creatures spread all over the world, much like a treasure hunt. There have been some reports that the game has motivated people, including children, to walk more and explore their surroundings. However, some critiques of the game are that people tend to focus more on the virtual than the physical environment.

In Geocaching – a mobile-based GPS enabled treasure hunt app – players hide physical containers in certain locations and record the GPS coordinates of the container's location on the Geocaching Web site which other players then use to find the containers (Neustaedter *et al.*, 2013). The containers usually contain some small exchangeable toys or trinkets and a paper log book with records left by all of the players that have found the container previously. The game, which started in 2000, now has over four million players worldwide (www.geocaching.com) and has been used by parents to motivate their children to get outside and experience nature around them (O'hara, 2008). The containers' locations can be in a forested areas, creeks, parks, etc., thus offering the chance for children to interact with the natural environment while having fun on a mission to reach the location and find the "treasure".

Chavez (2009) conducted an experiment where one group of children conducted a treasure hunt in a local park using traditional methods (children were given a list of items to locate along a trail and sketch in a notebook when they found them), while others used GPS to locate the hidden items. The study found that the children in the latter group were more enthusiastic and enjoyed the use of geocache technology on their treasure hunt while exploring the park.

Similarly, Nature Passport app (islandwood.org/nature-passport-app) uses mission-based activities to motivate children to explore nearby natural spaces, such as parks, creeks, woodlands, or even neighbourhood street trees. When a mission is completed, the user is rewarded with a virtual badge, encouraging kids to collect all the badges.

Most of these apps have the goal of getting kids outside, nudging them to experience nature in a more unstructured way, often using paradigms of exploring, seeking and hunting, without particular focus on educational curricula.

Contributory technology to engage children in citizen science activities

Citizen science projects provide opportunities for children to engage in outdoor activities that promote connections with nature and foster an understanding and appreciation of environmental concepts through hands-on engagement with natural systems (Kountoupes and Oberhauser, 2008). A study in Germany showed that school children were able to conduct an ecological experiment and collect qualitative data similar to scientists, however, research methods and topics should be tailored appropriately to their education level (Miczajka *et al.*, 2015). The Monarch Larva Monitoring Project is one of the most notable citizen science projects that involved children in data collection.

Mobile technologies have made it easier for everyone, including children, to participate in citizen science activities, most of the time only requiring the mobile phone that they usually carry. Project Noah uses a social media platform that enables people to take photos of their wildlife encounters and share them online through the website or mobile app with people around the globe. Images uploaded by users help scientists in many ways, including in investigating the changing patterns of species distribution and migration due to climate change, the spread of invasive species, and the presence of native species (National Geographic Society blogs, 2011).

Project Noah teamed up with the National Environmental Education Foundation and National Geographic Education to launch the Global Schoolyard Bioblitz mission. School children all over the world can use their mobile phone to collect and share wildlife observations from their schoolyards, encouraging them to get outside and explore. To date, the mission has shared almost 5,000 wildlife observations with more than 2,000 users participating (projectnoah.org/missions/10164691). The iNaturalist (inaturalist.org), the WildLab (thewildlab.org) and other similar apps provide similar opportunities for children.

The Global Soundscape project launched a Soundscape Recorder app which can be used by users to record and share sounds, including sounds of animals (biophony), earth-related sounds (geophony), and human-made sounds (anthrophony). After making recordings with the app, people are asked about what they heard and how they feel. The recording is then uploaded to the Global Soundscape database and can be accessed by anyone through web or

app (recordtheearth.org). An analytical and mapping tool enables users to see the distribution of sounds recorded.

With the growing use of mobile phones by children, which have camera and sound recording features, children can participate in citizen science activities. This provides opportunities for children to engage both in structured and unstructured ways as a participant in the context of a larger project or for personal interest.

DISCUSSION

We have identified several studies/projects, including mobile-based applications, related to efforts to connect children and adolescents with the natural environment. We described how the participation of children is structured and the role of technology use in each case. We found three broad themes to the structuring of participation in the environment through technology, instructional, exploratory and contributory. These findings have prompted us to explore how engagement with the environment might be expanded, in particular by children, through new research paths in HCI.

EXPANDING APPROACHES IN HCI FOR ENVIRONMENT

The term "Sustainable HCI" has been used to describe of HCI research that aims to promote environmental sustainability. It typically involves a persuasive approach to systems design that tries to persuade users to live in a more sustainable way (DiSalvo*, et al*., 2010; Foth *et* al., 2009; Nyström & Mustaquim, 2014). Notable works to map out Sustainable HCI are by Goodman (2009) and DiSalvo *et al* (2010). "Sustainable HCI" research has tended to subsume issues relating to the environment within sustainable living and environmental monitoring.

Goodman reviewed 120 HCI papers from 1998 to 2008 related to "nature", the environment" or "sustainability" and clustered them into three discourses of environmental HCI: "sustainable interaction design, re-visioning consumption, and citizen sensing". DiSalvo et al, building on Goodman's work, identified 157 papers up to 2009 and clustered the emerging "genres" of sustainable HCI. They identified approaches involving the design and use of persuasive technology, ambient displays to raise awareness, sustainable interaction design, formative user studies and pervasive and participatory sensing.

After reading the documents referred to in both papers, we found the focus on sustainable HCI to look at the planet in a fairly instrumental way, as a resource that should not be over exploited, because doing so will make it inhospitable for humanity. Much work is concerned with reducing consumption, particularly energy consumption and where understanding the environment is concerned, this is usually by monitoring through measurement. Dourish (2010) argued that HCI research on environmental problems has been self-limiting, particularly "by turning the problems of environmentalism into questions of personal moral choice and by turning environmental action into a redirection of consumption patterns".

We argue that HCI for environment could also be concerned with engaging people to care about the environment and nature on its own terms and for all of the beauty and wonder that it offers, instead of only seeing it in terms of sustainability. Moreover, as Light *et al* (2015) urged, a move toward technical tools can be both ecological and enchanting, to present a positive model of development and prompt transformation towards lived understanding of custodianship, cooperation and co-created resilience. In particular Light *et al* (2015) see the environment as something that we all share and as something that could be enjoyed and shared in the true sense of sharing, rather than in the transactional sense of trading. Moreover Light *et al* (2015) identified the need for tools to scale up, enabling participation at many levels, progressing growth in knowledge and sharing of expertise.

Building upon this, we envisage digital tools that can immerse and engage children with nature progressively and at many levels so that they grow ever more understanding of and connected to natural systems, local and global. There is a danger that tools and apps target discrete activities, with extrinsic rewards and motivations, rather than grow sustained knowledge and interest. Rogers (2010) emphasized that digital augmentation should not take away users' attention from their exploration but spark their thinking on its relation with the nature around them. Approaches that engage kids over time seem particularly important. Environmental education and awareness raising targeted at younger age audience has been overlooked in the discourse on sustainable HCI. We argue that children's engagement with nature plays a vital role in efforts to achieve a long term sustainable future and that expanding the scope and duration of their engagement with nature should be an area of greater exploration in HCI research.

Cumbo *et al* (2014) suggests motivation be considered in designing digital tools to inspire children's outdoor play, including: adventurous experiences, interaction with animals and plants, play and collaboration with other children, adult free environments, creativity and magic, finding and creating special places, physical challenges, affective elements and learning/cognitive challenges. Cottman-fields et al (2013), emphasized the importance of engaging intrinsic interest, rather than tasking participants with simple discrete activities. Similarly, we suggest approaches that build on intrinsically satisfying practices of engaging with nature, building observations and knowledge and connecting to nature over time.

CONCLUSION

This paper examined the research literature on facilitating children's interaction with the natural world through technology. We identified strategies that use technology to enhance curricular instruction, get children outside to explore, and engage them in citizen science. We conclude there is much scope for further work that expands HCI for environment beyond an instrumental view of sustainability, making it easier for children to engage with nature more deeply and in many more ways, so that they grow intrinsic interest, becoming ever more understanding of and connected to natural systems over time.

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REFERENCES

Ark, P. (2011). Climbing Trees : Getting Aussie Kids Back Outdoors. Retrieved from http://treeday.planetark.org/documents/doc-534-climbing-trees-research-report-2011-07-13-final.pdf

Arnold, H. E., Cohen, F. G., & Warner, A. (2009). Youth and environmental action: Perspectives of young environmental leaders on their formative influences. *The Journal of Environmental Education*, *40*(3), 27-36.

Audubon
http://www.audubon.org/apps

Chavez, D. J. (2009). Youth day in Los Angeles: Evaluating the role of technology in children's nature activities. *Children Youth and Environments*, *19*(1), 102-124.

Chawla, L. (1999). Life paths into effective environmental action. *The Journal of Environmental Education*, *31*(1), 15-26.

Cleland, V., Crawford, D., Baur, L. A., Hume, C., Timperio, A., & Salmon, J. (2008). A prospective examination of children's time spent outdoors, objectively measured physical activity and overweight. *International journal of obesity*, *32*(11), 1685-1693.

Clements, R. (2004). An Investigation of the Status of Outdoor Play. *Contemporary Issues in Early Childhood*, *5* (1), 68–80.

CNN (2011). Greg Hughes - http://edition.cnn.com/2011/HEALTH/06/01/myopia.caues/

Cooper, N. (2013). What's That Tree? Leafsnap Knows. *Learning & Leading With Technology*, *40*(6), 29

Cottman-Fields, M., Brereton, M., & Roe, P. (2013, April). Virtual birding: extending an environmental pastime into the virtual world for citizen science. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 2029-2032). ACM.

Cumbo, B. J., Jacobs, B. C., Leong, T. W., & Kanstrup, A. M. (2014, December). What motivates children to play outdoors?: potential applications for interactive digital tools. In *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: the Future of Design* (pp. 168-171). ACM.

DiSalvo, C., Sengers, P., & Brynjarsdóttir, H. (2010, April). Mapping the landscape of sustainable HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1975-1984). ACM.

Dourish, P. (2010, August). HCI and environmental sustainability: the politics of design and the design of politics. In Proceedings of the 8th ACM Conference on Designing Interactive Systems (pp. 1-10). ACM.

England, N. (2009). Childhood and nature: A survey on changing relationships with nature across generations. *Cambridgeshire: Natural England*.

Ferreira, I., Van Der Horst, K., Wendel-Vos, W., Kremers, S., Van Lenthe, F. J., & Brug, J. (2007). Environmental correlates of physical activity in youth–a review and update. *Obesity reviews*, *8*(2), 129-154.

Foth, M., Paulos, E., Satchell, C., & Dourish, P. (2009). Pervasive computing and environmental sustainability: two conference workshops.IEEE Pervasive Computing, 8(1), 78-81.

Grant, W. C. (1993). Wireless coyote: A computer-supported field trip. *Commun. ACM*, *36*(5), 57-59.

Geocaching
http://www.geocaching.com/

Goodman, E. (2009, April). Three environmental discourses in human-computer interaction. In *CHI'09 Extended Abstracts on Human Factors in Computing Systems* (pp. 2535-2544). ACM.

Hanscom, A. J. (2016). *Balanced and Barefoot: How Unrestricted Outdoor Play Makes for Strong, Confident, and Capable Children*. New Harbinger Publications.

Hinds, J., & Sparks, P. (2008). Engaging with the natural environment: The role of affective connection and identity. *Journal of environmental psychology*, *28*(2), 109-120.

iNaturalist
http://www.inaturalist.org/

Kountoupes, D. L., & Oberhauser, K. S. (2008). Citizen science and youth audiences: educational outcomes of the Monarch Larva Monitoring Project. *Journal of Community Engagement and Scholarship*, *1*(1), 10.

Leafsnap
http://leafsnap.com/

Light, Ann, Margot Brereton, and Paul Roe. (2015). "Some Notes on the Design of World Machines." In *Proceedings of the Annual Meeting of the Australian Special Interest Group for Computer Human Interaction*, pp. 289-293. ACM

Liu, T. Y., Tan, T. H., & Chu, Y. L. (2009). Outdoor natural science learning with an RFID-supported immersive ubiquitous learning environment. *Educational Technology and Society*, *12*(4), 161–175.

Louv, Richard. (2005) *Last child in the woods: saving our children from nature-deficit disorder* Chapel Hill, NC: Algonquin Books of Chapel Hill.

Meek, S., Fitzgerald, E., Sharples, M., & Priestnall, G. (2013). Learning on field trips with mobile technology. *On the Move: Mobile Learning for Development*, 179–195.

Merlin Bird ID
http://merlin.allaboutbirds.org/

Miczajka, V. L., Klein, A. M., & Pufal, G. (2015). Elementary School Children Contribute to Environmental Research as Citizen Scientists. *PloS one*, *10*(11), e0143229.

National Geographic Society blogs (2011). David Braun - http://voices.nationalgeographic.com/2011/10/22/project-noah-makes-scientists-of-us-all/

Nature Passport App | IslandWood
https://islandwood.org/nature-passport-app

Neustaedter, C., Tang, A., & Judge, T. K. (2013). Creating scalable location-based games: Lessons from Geocaching. *Personal and Ubiquitous Computing*, *17*(2), 335–349.

Nyström, T., & Mustaquim, M. M. (2014, November). Sustainable information system design and the role of sustainable HCI. In *Proceedings of the 18th International Academic MindTrek Conference: Media Business, Management, Content & Services* (pp. 66-73). ACM.

O'Hara, K. (2008, April). . In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1177-1186). ACM.

Ohashi, Y., & Arisawa, M. (2006, June). Nature talk: a proposed audible database system for environmental learning. In *Proceedings of the 2006 conference on Interaction design and children* (pp. 167-168). ACM.

Ohashi, Y., Ogawa, H., & Arisawa, M. (2008). Making new learning environment in zoo by adopting mobile devices. *Proceedings of the 10th International Conference on Human Computer Interaction with Mobile Devices and Services*, 489–490.

Palmer, J. A. (1993). Development of concern for the environment and formative experiences of educators. *The Journal of Environmental Education*, *24*(3), 26-30.

Palmer, J. A., & Suggate, J. (1996). Influences and experiences affecting the pro-environmental behaviour of educators. *Environmental Education Research*, *2*(1), 109-121.

Pergams, O. R. W., & Zaradic, P. A. (2006). Is love of nature in the US becoming love of electronic media? 16-year downtrend in national park visits explained by watching movies, playing video games, internet use, and oil prices. *Journal of Environmental Management*, *80*(4), 387–393.

Pijanowski, B. C., Farina, A., Gage, S. H., Dumyahn, S. L., & Krause, B. L. (2011). What is soundscape ecology? An introduction and overview of an emerging new science. *Landscape ecology*, *26*(9), 1213-1232.

Purdue Center for Global Soundscapes
http://centerforglobalsoundscapes.org/

Record the Earth
https://www.recordtheearth.org/

Rieger, R., & Gay, G. (1997, December). Using mobile computing to enhance field study. In *Proceedings of the 2nd international conference on Computer support for collaborative learning* (pp. 218-226). International Society of the Learning Sciences.

Rivet, A., & Schneider, R. (2004). Exploring the role of digital photography to enhance student inquiry in a local ecosystem. *Journal of Computers in Mathematics and Science Teaching*, *23*(1), 47–65.

Rogers, Y., Connelly, K., Hazlewood, W., & Tedesco, L. (2010). Enhancing learning: a study of how mobile devices can facilitate sensemaking. *Personal and Ubiquitous Computing*, *14*(2), 111-124.

Rogers, Y., Price, S., Fitzpatrick, G., Fleck, R., Harris, E., Smith, H., ... & Thompson, M. (2004, June). Ambient wood: designing new forms of digital augmentation for learning outdoors. In *Proceedings of the 2004 conference on Interaction design and children: building a community* (pp. 3-10). ACM.

Singer, D. G., Singer, J. L., Agostino, H. D., & Delong, R. (2009). Children's Pastimes and Play in Sixteen Nations Is Free-Play Declining? *American Journal of Play*, *1*(3), 283–312.

Suzuki, M., Hatono, I., Ogino, T., Kusunoki, F., Sakamoto, H., Sawada, K., … Ifuku, K. (2009). LEGS system in a zoo: use of mobile phones to enhance observation of animals. *Interaction Design and Children*, 3.

The WildLab
http://thewildlab.org/

Wells, N. M., & Lekies, K. S. (2006). Nature and the life course: Pathways from childhood nature experiences to adult environmentalism. *Children Youth and Environments*, *16*(1), 1-24.

White, R. (2004). Children's Outdoor Play & Learning Environments: Interaction with Nature during the Middle Years: Its Importance to Children's Development & Nature's Future. Retrieved from https://www.whitehutchinson.com/children/articles/downloads/nature.pdf

Yahya, S., Ahmad, E. A., & Jalil, K. A. (2010). The definition and characteristics of ubiquitous learning: A discussion. *International Journal of Education and Development using Information and Communication Technology*, *6*(1), 1.