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A conceptual model for teaching the relationship of daily life and human environmental impact to ecological function

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In the general activity of daily life, it is easy to miss our dependency on the Earth's ecology. At the same time that people are living apparently separate from the environment, our impact on the Earth is increasing. This study seeks to understand how teachers can bridge this persistent disconnect of daily life from ecology and human impact. Specifically, this study addresses teachers' use of a conceptual model for teaching ecology and human impact units that link daily life, human impact and ecological function. Thirty-six ninth grade biology teachers implemented curriculum that was grounded in an explicit conceptual model for teaching the relationship between ecological function, human impact, and daily life. Pre and post implementation, teachers completed detailed descriptions of their lesson plans for teaching ecology and human impact topics. Content analysis of teacher lesson plan descriptions shows that teachers have a greater difficulty integrating daily life and human impact into ecological topics than they do in integrating daily life and ecology into human impact topics. This study also documented the difficulty of applying a conceptual model that overtly connects daily life and human impact to ecological function. Despite this, the implementation of curriculum grounded in an explicit conceptual model for linking daily life, human environmental impact and ecology helped teachers articulate those connections in ways that could enable students to understand the unintended consequences of daily life activities on specific ecological function.

Key words: ecological literacy, environmental education, environmental science, science education, human impact, ecological function

Introduction

Whether for the food we eat or the air or water we consume, people, like all things that are alive, interact and depend upon the living and non-living components of the biosphere for survival. Yet in the general activity of daily life, it is easy to miss our dependency on the Earth's ecology. Food purchased from a grocery store, water retrieved from a tap, and air breathed as a matter of course, allow people to live without considering the rest of the world on which we rely. At the same time that people are living apparently separate from the environment, our impact on the Earth is increasing (Miller, 2005; NSF ACRE, 2003; 2005; 2009). This study seeks to understand how science teachers bridge this persistent disconnect of daily life from ecology and human environmental impact. Specifically, this study addresses teachers' use of a conceptual model for teaching ecology and human environmental impact units that links daily life, human environmental impact and ecological function.

Conceptual Framework

Conceptions of Nature and the Environment

Studies of student conceptions of nature, the environment, and human environmental impact consistently show that children understand people to be disconnected from the rest of the living world. Investigations of student characterizations of nature show that most primary school students view nature as a place without people, where only plants and animals live (Bonnet & Williams, 1998; Littledyke, 2004). Others have documented that both primary and secondary school students see nature as pristine, as areas untouched by people or urban environments (Payne, 1998a; 1998b; Alerby, 2000). Still other studies reveal student difficulties with picturing the existence of wildlife in urban areas or the built environment (Simmons, 1994; Membiela, Nogueiras & Suarez, 1994).

Studies specifically seeking to document student perceptions of the environment have found a similar pattern of separating humans from the environment. A study of environmental survey responses from European students, aged 10-18 indicated that students tend to see humans as disconnected from the environment (Filho, 1996). Analyses of student responses to the open-ended prompt, "I think the term/word environment means . . ." showed that many students view the environment as "something out there" independent from their lives and humanity (Loughland, Reid, & Petocz, 2002). Like earlier studies seeking to characterize student perceptions of nature, Shepardson and colleagues (2007) also found in a study of upper elementary through secondary school students that students view the environment as a setting that contains plants and animals, but that does not contain people.

Analyses of student perceptions of human environmental impact show a similar trend. Tsurusaki and Anderson (2010) found that primary, middle and high school students have difficulty tracing the impact of human activities, in this case the impact of a hamburger supply chain and dishwashing, on the environment. Student concern about the impact of human caused pollution was disproportionally focused on how pollution might harm humans rather than on pollution's impact on other living things (Myer et al., 1999, 2000; Kahn & Friedman, 1995). Additionally, many Texan high school students were found to be unaware of the role of urbanization in habitat and species loss (Miller, 2005). Finally, survey responses from Australian primary school students show that many children are unfamiliar with their direct dependence on other living things for daily existence. For instance, many children do not know that the milk they consume is produced by cows and that the cotton they wear is from plants (Miller, 2005).

Yet not all children see themselves as distinct from the environment or nature. In multiple studies in the same rural region of the United States of Menominee nation and European American conceptualizations of the place of humans in nature, researchers found that adults and children of the Menominee nation were more likely than European Americans to view nature holistically and to be able to make generalizations from animals to people (Bang, Medin, & Atran 2007; Ross, Medin, Coley, & Atran, 2003; Atran, Medin, & Ross, 2004). Importantly, European American children (ages 4-10) justified their inability to make connections from animals to people on the basis that people are not animals. Menominee children were much less likely to use this reasoning. Furthermore, Menominee children of all ages were much more facile at making ecological connections amongst living things, whereas only the very oldest European American children were able to make these connections (Atran, Medin, & Ross, 2004; Ross, Medin, Coley,

& Atran, 2003).

The precociousness that Menominee children demonstrate through their ecological understanding is also mirrored in their early science test scores with 50% proficient in fourth grade as compared to the national average of 29% proficient. Yet additional formal schooling leads to a decline in Menominee science performance, with only 17% proficient in eighth grade, lower than the national average of 27%. School science is not capturing the cultural advantages that Menominee children bring to the science classroom (Bang, Medin, & Atran, 2007).

One apparent cultural difference in school learning of ecology is reflected in how elementary school teachers tend to view the environment. Like many of their students, elementary school teachers in the United States also tend to view people as separate from the environment (Moseley, Desjean-Perrotta, & Utley, 2010). This pattern was also shown for Greek kindergarten teachers who tended to view nature romantically and the environment as lacking complexity (Flogaitis & Agelidou, 2003). Furthermore, a study of Slovenian biology teachers showed that they too viewed nature as a place where people are largely absent and the environment as a place dominated by human activity such as pollution and environmental degradation (Torkar, 2009). If teachers have difficulty connecting people to the environment and nature, then it is likely that school children will develop this same difficulty.

In an effort to explicitly link daily life to ecology, this author developed a conceptual model for bringing daily life, human environmental impact, and ecological function into one study topic in the secondary school classroom setting (Wyner & Desalle, 2010; Figure 1). The goal of this model, developed as an NSF funded initiative and called *Ecology Disrupted*, is for students to learn about the importance and complexity of normal ecological function, by studying the environmental issues that result when daily life actions *disrupt* them. This model uses the same intellectual approach that the field of genetics uses to understand gene function. Simply put, geneticists learn gene function by studying the changes in appearance that result from mutations that disrupt normal gene function. In the *Ecology Disrupted* model, biology high school students learn the complexity of functioning ecosystems by studying the environmental issues that result from daily life actions that disrupt normal ecological function. Using ecological disruption to mediate the relationship between environmental issues and daily life, unlocks the ecological complexity that connects daily life to environmental issues and shows students the important role that ecology plays in their lives.

Conceptual Models and Educative Curriculum

Considerable research has been undertaken to understand teacher beliefs and models of various concepts (Nespor, 1987; Pajares, 1992; Clark, 1998) including the perspectives that teachers bring to teaching related to culture (Bryan &Atwater, 2002), classroom practice (Calderhead & Robson, 1991), the environment (Moseley, Desjean-Perrotta, & Utley 2010) and to teaching in general (Goodman, 1988; Powell, 1992). This research is important because it informs researchers of the teachers' beliefs and values that contribute to their classroom practice and to their conceptual models of how to present particular scientific concepts (Moseley et al., 2010).

Conceptual models are important because they interact with student mental models of target scientific concepts. Created by teachers and scientists, they are designed to help students develop appropriate and accurate models of the scientific concepts of interest (Norman, 1983). Students are considered to have successfully learned a concept when their prior mental models transform into the conceptual models of teachers and scientists (Duit & Glynn, 1996).

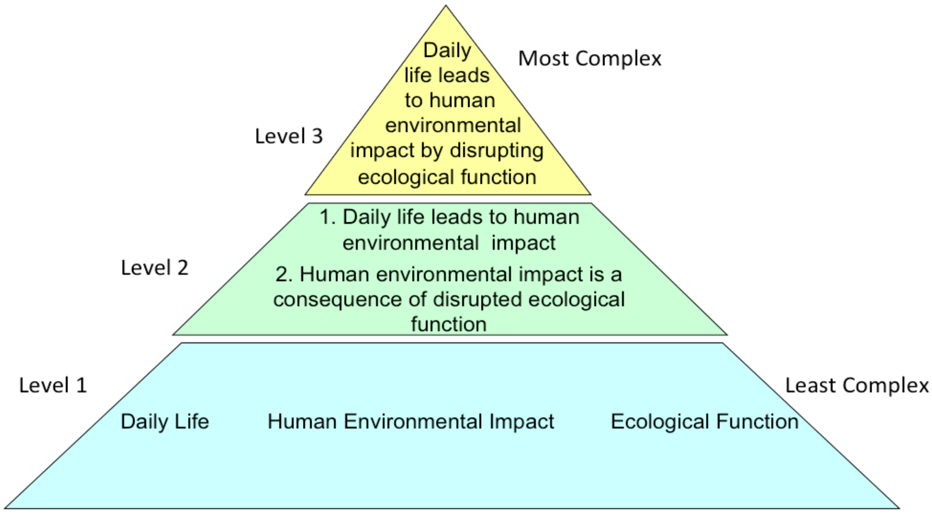

Figure 1. Figure 1 illustrates the hierarchical relationship amongst the key concepts in the conceptual model. Concepts higher in the hierarchy pyramid are dependent on concepts further down the pyramid. This model shows how ecological interactions mediate the cause and effect relationships between daily life (cause) and human environmental impact (effect).

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This idealized description of student learning has been shown to occur only infrequently, since very often students do not even see the whole model and only take from it the elements that seem relevant to them (Greca & Moreira, 2000). The difficulty that students have recognizing the different facets of conceptual models makes well-designed conceptual models even more important for student learning. In fact, we now have considerable understanding of how people learn, which we can use to address student evolving mental models of scientific topics (Bransford et al., 2000; Duit & Treagust, 2003).

Exposing teachers to new curriculum is an important approach for improving teacher conceptual models and for bringing new science content and teaching strategies to K-12 classrooms (Ball & Cohen, 1996; Beyer, Delgado, Davis, & Krajcik, 2009). Educative curriculum seeks to affect lasting change in teaching approaches by creating curriculum that influences teachers' perspectives on content and teaching strategies (Davis & Krajcik, 2005). These curricula have been shown to improve teacher learning by including important curricular supports to deepen teacher content knowledge beyond that required of the student and also to assist teachers' pedagogical content knowledge (Schneider & Krajcik, 2002; Davis & Krajcik, 2005; Collopy, 2003; Remillard, 2000).

The Study

The goal of this research is to understand the ways in which teachers use a conceptual model for teaching that links daily life, human environmental impact, and ecological function and to learn how using this curriculum, based on the *Ecology Disrupted* conceptual teaching model described above, affects how teachers' link these topics to one another. The salient research questions are:

1. What are teachers' conceptual models for connecting daily life, human environmental impact, and ecological function to one another?

2. How do teachers' conceptual models change through implementing *Ecology Disrupted* units that explicitly link daily life, human environmental impact, and ecological function to one another?

Methodology

Demographics

In total, data were collected from 36 biology teachers representing nineteen public New York City high schools in a large urban public school system located on the east coast of the United States.All the teachers in this study followed New York City's scope and sequence guidelines of this large urban district that required teachers to specifically address ecology content in the fall and human environmental impact con- tent in the spring (NYCDOE 2013). The average teacher had 11 years of experience, with a median of 8 years teaching. Teacher experience ranged from a high of 33 years teaching science to a low of 3 years teaching. Six teacher participants taught for greater than 20 years and six teachers taught for fewer than five years. All teacher participants were state certified and all but five were certified to teach biology. Of the five teachers who were not certified in biology, two teachers were certified to teach special education and the other three teachers had either a major or minor in a biological discipline. All of the teacher participants had master's degrees and one teacher had a Ph.D. in a biological field. More participants were female (N=23) than male (N=13). Eighteen teachers self-identified as white, three as African American, two as Latino/a, eight as Asian, and five as other, an increasingly common identification choice for Latinos (Navarro 2012).

Research Design

In the spring of 2011, 36 ninth grade biology teachers implemented two case studies (13 class lessons total) that were grounded in the *Ecology Disrupted* conceptual model for teaching how ecological function, human environmental impact, and daily life are connected. One case study focused on the consequences of salting roads for safe travel on the non-living and living ecosystem components of Baltimore stream ecosystems. The other unit focused on the consequences of rapid highway travel on genetic diversity and breeding amongst different bighorn sheep populations in the desert habitat between Los Angels and Las Vegas (units are available online at http://www.amnh.org/apps-and-kiosks/ecology-disrupted/).

In the spring 2010, prior to implementation, teachers completed questionnaires and surveys about their lesson plans for teaching ecology and human impact topics and about their attitudes and experience integrating these topics. In January 2011, teachers participated in a one-day workshop in which they learned how to enact the curriculum and they completed an exercise in which they developed new "*Ecology Disrupted*" examples from an extensive online repository of media about published scientific research on environmental issues. Following the workshop, teachers modified their initial lesson plans for teaching ecology and human impact topics. Then teachers implemented the 13 lesson *Ecology Disrupted* case studies in their classrooms. In June 2011, upon completion of curriculum implementation, teachers again modified their previously submitted lesson plans for teaching ecology and human impact topics and completed surveys about their attitudes towards integrating these topics. Teachers also submitted feedback through focus groups, surveys, and lesson logs about the strength and weaknesses of the curriculum.

Teacher Lesson Plan Questions and Survey Items

All the teachers in this study taught ecology units in the fall and human impact units in the spring as recommended by the scope and sequence guidelines of the district. As such, in order to develop baseline understanding of how teachers connect daily life, human environmental impact, and daily life, teachers were asked to complete questions about typical ecology and human impact lessons prior to implementing the *Ecology Disrupted* curriculum. The participants responded to the following:

"Describe an example of how you directly teach about:

1. Daily life impacts on the environment in the ecology section of the curriculum?
2. Daily life and human impact in a typical food web lesson?
3. Ecological concepts, daily life, and scientific data about human impact in a typical lesson on pollution?"

Questions 1 and 2 were chosen to better understand how teachers integrate daily life and human impact into ecology lessons and question 3 was chosen to understand how teachers integrate daily life and ecology into human impact lessons. Question 1 was a general question about ecology, while Question 2 was about a specific ecological topic, since the general ecological focus of question 1 may have been more difficult for teachers to consider. The specific topic of food webs was chosen for its suitability for integrating daily life and human impact, for the fact that the curricular intervention did not include this topic, and because it is a mandatory part of the 9th grade biology curriculum, meaning that the topic was familiar to all the teacher participants. Like food webs in question 2, pollution is a required topic of the 9th grade curriculum. The topic was deemed sufficiently focused to remind teachers of their lessons, but general enough to include many human environmental impact themes.

To ensure complete baseline data, teacher responses to these questions were reviewed and teachers were asked to clarify their responses in writing if their initial responses were considered to be incomplete or unclear. To measure how the *Ecology Disrupted* conceptual model for teaching affected teachers' approach to linking ecological function, human environmental impact, and daily life, teachers were asked to modify their responses to these lesson plan questions, following the *Ecology Disrupted* workshop and after they completed their implementation of the *Ecology Disrupted* curriculum.

Prior to implementation, teachers ranked, on a 5 point Likert scale, the degree of integration of human impact and ecology in their current curriculum and the importance that they ascribe to integrating these topics (appendix 1). Post implementation, teachers again responded to the Likert items asking them to rank the importance of integrating these items. Three education researchers reviewed and provided feedback on lesson plan and Likert scale survey questions and validated them as a method for learning how teachers integrate daily life, human impact, and ecology into one study topic. The Wilcoxon signed rank test was used to calculate the significance of differences in teacher responses.

Content Analysis

Content analysis was performed on teacher responses to the lesson plan questions and a rubric was developed to record the presence or absence of key concepts in each question (Krippendorf, 2005; Appendix 2). The key concepts measured are hierarchically related to one another in a three-level pyramid (See Figure 1). The simplest and lowest level of the pyramid was measured by whether the teacher responses mentioned daily life, human environmental impacts, or ecological concepts, the objects solicited in the question. The second or mid-level of the pyramid was measured by whether teacher responses documented the relationship between daily life and human environmental impact or the relationship between environmental impact and disrupted ecological function. Finally, the most sophisticated and highest level of the pyramid was defined as responses that documented the relational connection of daily life and human environmental impact to ecological function. Responses were considered to have done so if both steps of the midlevel pyramid were completed, i.e. teachers showed how daily life can lead to an environmental impact (Step 1) and teachers showed how human environmental impacts are the consequences of disrupting normal ecological function (Step 2).

Two people evaluated teacher responses for the presence or absence of these key concepts. One grader, the author, is trained as a conservation biologist and has a background as an educational researcher. The other grader is a post-baccalaureate in biology with a specific focus in ecology. Prior to grading items, the two graders calibrated and adjusted their rubrics based upon their review and discussion of responses from teachers who did not complete the study. Krippendorf's alpha was calculated to measure the reliability of grading between graders for each of the 19 categories on the rubric (see tables for all categories). The values ranged from a low of 0.82 to a high of 1 for some easy to agree items like mentioning the ecological concept of food webs. These results indicate a high degree of inter-rater reliability.

Chi-square tests were calculated on teacher responses to all three questions pre and post intervention to measure whether the ability of teachers to link daily life, ecology, and human impact was affected by the intervention. Additionally, chi-square tests were also used to compare teacher responses to the different questions to determine whether they found integration of these concepts easier in some contexts than others, i.e. How did the topic choice, ecology or human impact affect the ability of teachers to connect daily life, human environmental impact, and ecological function to one another?

The Intervention

Teachers implemented two *Ecology Disrupted* case studies that explore the relationship between ecological function and human environmental impact in the context of daily life. The case studies are based upon media about and data from published research about the impact of road salt on increasing salinization of freshwater streams and the impact of highways on reducing breeding amongst bighorn sheep populations (Kaushal et al., 2005; Epps et al., 2005). Each case study is constructed around a question that asks students to link everyday human actions to the environmental issue that is the topic of the published research. One seven class lesson case study asks students "How might snowy and icy roads affect Baltimore area's water supply?" and another six class lesson case study asks "How might being able to drive from Los Angeles to Las Vegas in just four hours put the bighorn sheep at risk?" Students investigate case study specific data to learn how salting roads in Baltimore and how highways in the desert mountains between Los Angeles and Las Vegas disrupt particular ecological functions. For example, the Baltimore case study is used to help students learn how salting roads for safe travel disrupt abiotic and water runoff ecology in the Baltimore watershed, eventually leading to saltier drinking water supplies. The bighorn sheep example is used to help students learn how highways, built to connect Las Vegas to Los Angeles and help the Vegas economy, disrupt bighorn sheep habitat ecology, thus making it hard for sheep from different mountaintop populations to mate, and leading them to become inbred.

Students are asked to consider sustainable solutions for both these issues to avert ecological disruption and the consequent environmental issues. For example, for Baltimore roads, they suggest using alternative solvents to melt snow and ice in Baltimore to avoid disrupting abiotic stream components and in the bighorn sheep example, they suggest elevating sections of Nevada's highways to avoid disrupting bighorn sheep habitat and to allow sheep and other animals to cross under the highways in order to mate with animals on neighboring mountains.

Finally, students are asked to apply the same methodology to other environmental issues that are caused by different human actions that disrupt the same ecological function. For example, students learn how the environmental issue of light pollution caused by the basic desire for people to see at night, changes abiotic ecosystem components. This change in abiotic environmental factors harms living organisms like aquatic insects that lay their eggs at night. These insects perceive the artificially lit surfaces as water and consequently lay their eggs on dry land. After students connect the environmental issue to ecological function and daily life, they once again develop sustainable solutions that recognize the human and ecological components of the environmental issues. In the latter example, students can research and describe new types of lights designed to reduce scattered light rays. These lights help people see better at night and also help to reduce the effect of artificial light at night.

The curriculum was designed using the educative curriculum framework (Davis & Krajcik, 2005). As such the curriculum contains supports that have been shown to help teacher learning and implementation of curriculum (Collopy, 2003; Davis & Krajcik, 2005; Remillard, 2000; Schneider & Krajcik, 2002). Additionally, teachers participated in a one-day professional development program to enhance their learning of curricular content and pedagogical content knowledge (Franke, Carpenter, Fennema, Ansell, & Behrend, 1998).

Results

Teachers began the program stating that they highly integrated their human impact and ecology curriculum and that they highly valued doing so (Figures 2 and 3). Although teachers report a significantly higher integration of ecology into their human impact section of the curriculum, the level of integration they report for human impact into their ecology curriculum is also very high (Figure 2). It should be noted that teacher attitude responses were affected by the use of 5 point Likert scale. Twenty-five teachers (N=36) on the pre-survey topped out the scale for the item asking teachers to rate the importance of integrating ecology into the human impact section of the curriculum (Figure 3). On the post survey, 30 teachers topped out the scale. A survey with a longer scale may have yielded more refined results (Figure 3). However, given these limitations, a Wilcoxon match-pairs signed ranks test indicates that post implementation teachers placed a significantly (p=0.05) higher value on integrating human impact into the ecology section of the curriculum than they did prior to implementation (Figure 3).

Responses to Question 1: Describe an example of how you directly teach about daily life impacts on the environment in the ecology section of the curriculum?

Analysis of the teacher initial lesson plan reports and subsequent modifications (N=34) to the question, “Describe an example of how you directly teach about daily life impacts on the environment in the ecology section of the curriculum?” showed a number of patterns for how teachers connect daily life and human impact to ecology. Responses were tallied for the presence of parameters shown in Table 1.

Content analysis for the presence or absence of daily life impacts or ecological topics, the items that comprise the base of the conceptual pyramid showed that many teachers did not even include the objects solicited in the question in their responses (Figure 1, Table 1). In the case of daily life impacts, the major focus of the lesson planning prompt, only 41% of initial responses mention daily life impacts. Teachers were more successful in mentioning a specific ecological principle, the other major focus of the prompt, in their responses. Yet, even so, greater than 50% of teachers did not mention an ecological principle in their responses.

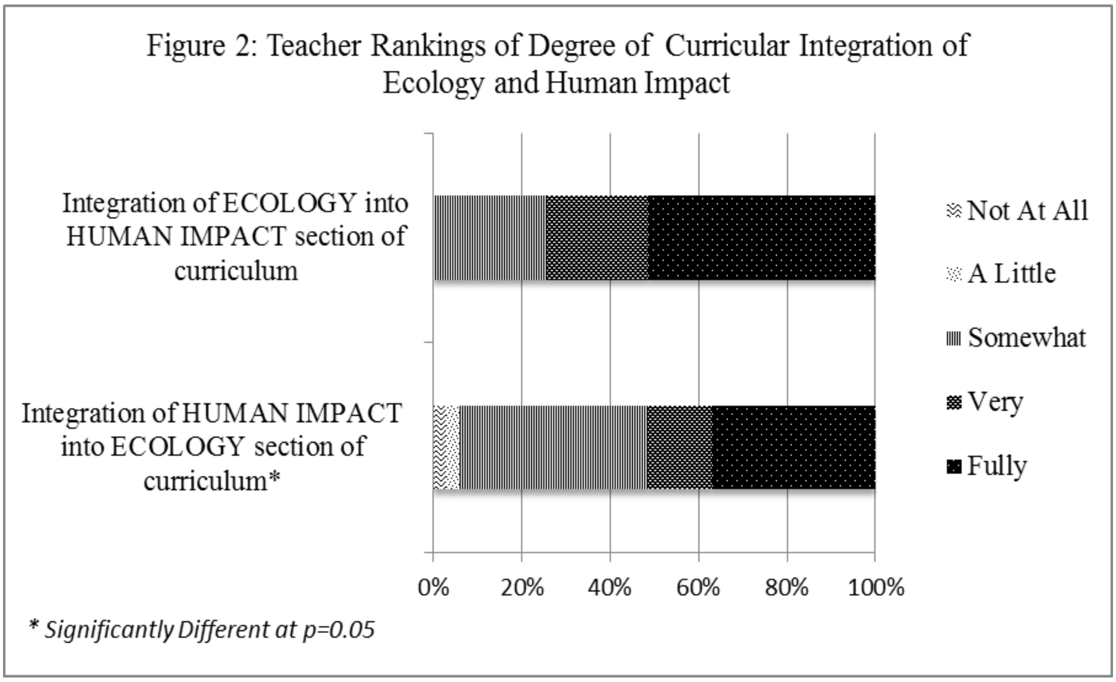
Figure 2: Teacher Rankings of Degree of Curricular Integration of Ecology and Human Impact
Integration of ECOLOGY into HUMAN IMPACT section of curriculum
Integration of HUMAN IMPACT into ECOLOGY section of curriculum*
Not At All
A Little
Somewhat
Very
Fully
0%
20%
40%
60%
80%
100%
* Significantly Different at p=0.05

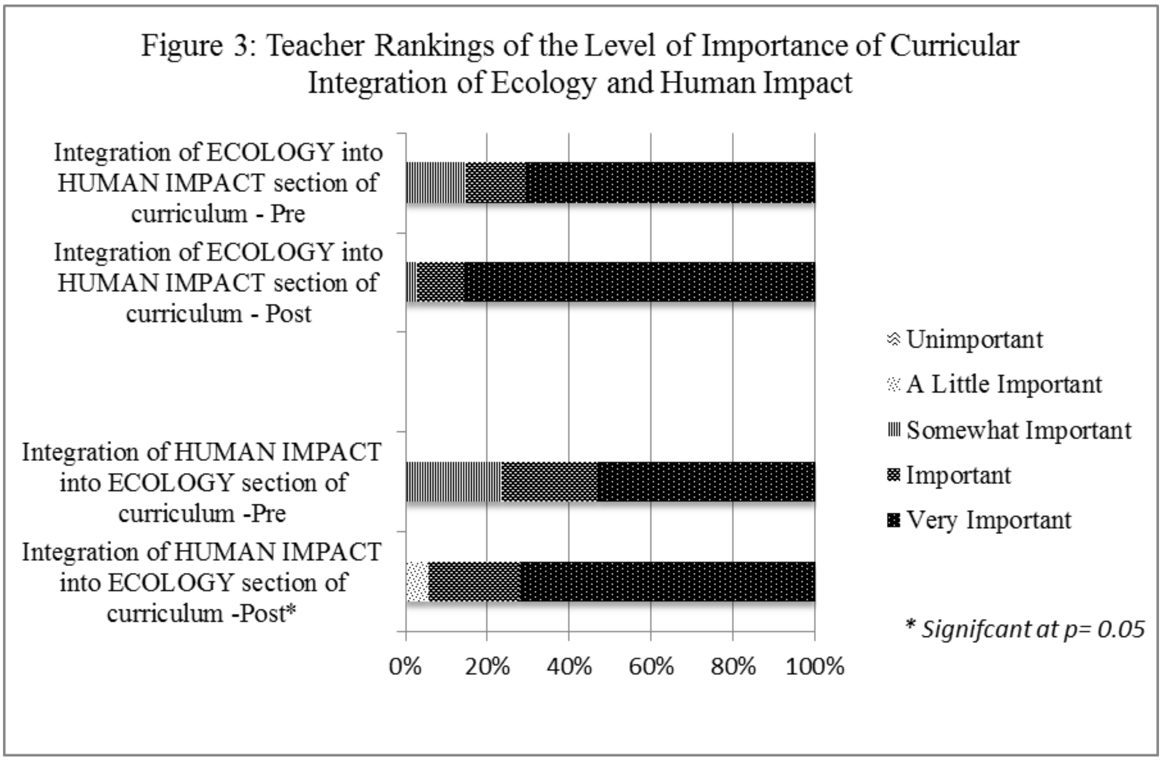
Figure 3: Teacher Rankings of the Level of Importance of Curricular Integration of Ecology and Human Impact
Integration of ECOLOGY into HUMAN IMPACT section of curriculum - Pre
Integration of ECOLOGY into HUMAN IMPACT section of curriculum - Post
Integration of HUMAN IMPACT into ECOLOGY section of curriculum -Pre
Integration of HUMAN IMPACT into ECOLOGY section of curriculum -Post*
Unimportant
A Little Important
Somewhat Important
Important
Very Important
* Signifcant at p= 0.05
0%
20%
40%
60%
80%
100%

Table 1. Percent of Pre and Post Responses (N=34) That Mention or Connect Daily Life, Human Impact, or Ecology Themes in the Ecology Section of the Curriculum

	Mention Ecology Topic	Mention Impact of Daily Life Action	A. Connect Impact of Daily Life Action to Ecology (part 1 and 2)	B.[a] Connect Only Daily Life Actions to Human Impact (part 1 only)	C.[a] Connect Only the Impact of Human Action to Ecology (part 2 only)	Connect the components of daily life impacts to ecological function (summation of columns A, B, &C)
Pre Implementation	47%	41%	12%	12%	9%	31%
Post implementation	79%*	76%*	50%*	9%*	9%*	68%*

***** indicates post values are significantly higher than pre values at p=0.05.

[a] column B and C pre-post comparisons take the part 1 and part 2 connections made in column A into account when calculating pre-post differences (e.g. post implementation part 1 connections were made 59% of the time as compared to 24% of the time pre implementation).

Further examination of responses shows a number of reasons why teachers did not include daily life impacts and/or an ecological principle in their responses. For the lack of daily life impact inclusion, 15% of teachers reported that they do not connect daily life impacts to ecology in their classroom. Another 15% of teachers treated human impact as synonymous with daily life as shown by their replacement of daily life impacts in their responses with discussion of human impact topics like pollution, the BP oil spill and deforestation. Finally, many responses were vague, making it difficult to identify “daily life” in their responses. For example, one teacher responded, “the human occupies a place at the top of a food chain,” and another teacher wrote, “reminding students of the importance of respecting the environment and preserving biodiversity in nature”. These responses may have daily life impact connections, but they cannot be inferred from the limited teacher description.

The missing ecological component is likely due to the fact that many teachers chose to focus their response on environmental impacts rather than seeking to connect their responses to an ecological function. For example, one teacher’s 75-word lesson description contains a detailed description of his own daily life to show how he reduces his environmental impacts, but he does not connect the environmental impacts back to any particular ecological function.

Connecting Daily Life Impacts to Ecology

Analyses of initial teachers’ responses show that few teachers (12%) in their responses to question 1 connected the impact of daily life action to ecological function (Table 1; level 3 in Figure 1). Teacher responses were also evaluated for the presence or absence of the two relational components that comprise the highest level of the conceptual model, daily life impacts ecological function. These two components individually comprise the mid level of the conceptual pyramid: 1. Daily life leads to human environmental impact (Part 1). 2. Human environmental impacts are the unintended consequences of *disrupting* normal *ecological* function (Part 2). Just 31% of teachers’ initial responses were found to describe any component of the impact of daily life on ecological function (level 2 or 3 of Figure 1).

Close reading of the initial teacher responses that successfully linked daily life to human environmental impact, but not to ecological function (Part 1 only) show how connecting daily life to human impact personalizes what on the surface appears to be human actions unrelated to the lives of students. Below are three of the teacher responses that connect daily life action to human environmental impact, but do not connect to ecological function:

> 1. "Students record the number and length of time they use lights and how much water
> they use for a week. The class then calculates how much energy they use and translates the number into barrels of oil used."
> 2. "How driving cars changes carbon dioxide levels"
> 3. "The impact of local sewage overflows on the oxygen levels in the ocean. The sewage feeds microorganisms that use up the water's oxygen, which in turn causes fish to die."

Each of these examples shows how including daily life in a discussion of human environmental impact enriches student connections to the topic. Response 1 gives meaning to the measurement "barrels of oil" by translating it into the energy required to perform daily life activities. This term, "barrels," may have been particularly meaningful to students during the time this teacher reported her lesson since the Gulf oil spill occurred at the same time as these lessons were implemented. This lesson report would have been even stronger, if it explicitly connected to the events of the Gulf. Response 2 focuses on driving which also personalizes human impact, in this case, the rising carbon dioxide levels. Response 3 also builds on personal connections to human impact by connecting local sewer overflows to the waterfront, located a few steps from this school. Expanding on these responses to overtly connect them to ecology (responses 1 & 2 to the carbon cycle; response 3 to the nitrogen cycle) would make ecological function more meaningful to students by showing how daily life impacts these ecological functions.

Exploration of the lessons that describe part 2 of the *Ecology Disrupted* approach (figure 1, level 2, part 2), the environmental issues that result from human actions that disrupt normal ecological function, show how this approach can make normal ecological function visible to students. Below are two of the teacher responses that connect human environmental impact to ecological function, but not to daily life:

1. "Using biomagnification with food chains to show how human-produced chemicals can affect organisms at different trophic levels"
2. "Asking students how removing a species from a food chain or food web by overhunting and deforestation might affect the population of other organisms"

These responses demonstrate how nesting human environmental impact in ecological function expands understanding of both concepts. In both responses, human impact is critical for building understanding of the ecological concept and the ecological concept, in turn, informs understanding of human impact. Biomagnification illustrates the ecological concepts of trophic levels, and in turn, an understanding of trophic levels feeds back into understanding the consequences of releasing human-produced chemicals into the environment. The suggested exercise in response two also reciprocally informs an understanding of human impact and ecological function. Removing species from a food chain or food web illustrates this ecological concept by showing the dependency of organisms in the chain/web on one another. It also illustrates the impact of overhunting as more than just the loss of the hunted species. Connecting these examples to daily life would further strengthen these examples by personalizing them for students. For example biomagnification of mercury in fish like tuna is related to mercury air pollution from burning coal to make the electricity that powers such everyday items like refrigerators, computers, phones, and lights.

Bringing parts one and two together to link the impact of daily life actions to ecological function can both personalize human impact and ecological function and lead to a greater understanding of how daily life leads to ecological disruption. Below are the five teacher responses that connect the impact of daily life action to ecological function (italicized; level 3 in Figure 3):

1. "Packaging of personal care products leads to the consumption of non-renewable resources that leads to fossil fuel use that in turn leads to climate change and *habitat* destruction."
2. "How plastic salad containers, Chinese food containers, tires, and water bottles ruin *ecosystems* and living things."
3. "How daily actions influence the *carbon cycle* and global warming."
4. "The bus and subway use fossil fuels that impact pollution levels which in turn affects the *carbon cycle*."
5. "Students research what we as Americans consume and how to reduce our carbon footprint . . . Students researched the organisms that live in the Gulf and organized them into *energy pyramids* to explain how the spill caused disruptions at each level."

Each of these responses at least partially achieves the aims of overtly linking daily life actions to ecological function. Responses 1 and 2 use specific elements of daily living to successfully conjure daily life, yet neither response explicitly shows the ways daily behavior impacts habitats or ecosystems. Including examples that explain the specific ways ecosystems, habitats, and species are impacted can strengthen these lesson plans. Response 3 more thoroughly connects daily life to a consequence of disrupting the carbon cycle, global warming, yet this example does not include the necessary detail to bring daily life alive. Response 4 also connects daily life to the carbon cycle, and in this case includes more description of daily life, yet this example does not explain what happens when the carbon cycle is affected. Response 5 most successfully links daily life to human impact and to ecological disruption. By linking the Gulf oil spill to our carbon footprint, this teacher emphasizes the personal connection between daily life needs and the Gulf spill (Part 1). Asking students to also consider the effect of the oil spill on each level of the energy pyramid provides students with a more nuanced understanding of the spill's impacts and also of the ecological relationships that energy pyramids describe (Part 2).

Teacher Lesson Modifications

Teachers were asked to report and then modify their initial lessons about how they integrate daily life impacts into ecology in order to measure teacher change in how they use daily life impact to understand ecology, a major aim of the curriculum. Lesson modification responses show that many teachers improved in this area, particularly in the lower levels of the conceptual model (Figure 1; Table 1). The number of teachers mentioning the impact of daily life, human impact, and ecology grew, with the number of teachers mentioning the impact of daily life nearly doubling (table 1). Analysis also shows that the number of teachers whose ecology lessons grew to include the relational connection between the impact of daily life on ecological function or to one of its component concepts, daily life leads to human environmental impact and humans environmental impact is the result of disrupted ecological function, grew from 31% prior to the implementation to 68% post implementation. Most of the additional connections made were through integrating portions of the two major case studies from the *Ecology Disrupted* curriculum, i.e. exploring the impact of salting roads for safe travel on abiotic stream components and the role of highways, built to make travel quicker on disrupting bighorn sheep habitat and populations.

The specific influence of the curriculum on teacher responses can be seen by the daily life, human environmental impact, and ecology themes described by teachers in their pre and post implementation responses (Table 2). Pre implementation, most discussions of daily life impacts centered on fossil fuel use and recycling. Post implementation discussions centered on *Ecology Disrupted* topics like salt, roads, drinking water, light pollution, and the urban heat island effect. The same pattern holds for ecology and human environmental impact themes. Pre implementation ecology discussion focused on a number of topics with a slightly higher focus put on the carbon cycle and food webs. Post implementation ecology topics focused on *Ecology Disrupted* themes, like abiotic and biotic factors, water cycle, habitats, populations, and genetic diversity. For human impact, pre implementation themes focused on climate change and oil spills and post implementation themes focused on *Ecology Disrupted* topics like how changing abiotic factors impacts biotic factors, biodiversity, and ecosystems and the impact of habitat fragmentation.

The human impact themes described by teachers in their post-implementation responses demonstrate that, for some teachers, understanding of human environmental impact grew to include ecological disruption. Post implementation, 59% of teacher responses linked human impact to ecological function as opposed to 21% previously. Some of these teachers explicitly described human impact in ecological terminology. One teacher's post implementation response summarized what we were hoping for:

> I really like the emphasis on the concept that humans change abiotic factors that then impact biotic factors. I think I will continue to use this as the "lens" through which ecology or human impact is taught.

The analysis shows that while many teachers exhibited growth in their ability to connect daily life to human impact and ecological function, fewer teachers actually appeared to transform how they approach this topic. Over 30% of teachers did not even achieve the mid-level of the conceptual model in their post implementation responses, i.e. they did not connect daily life to ecological function; daily life to human impact; or human impact to ecological function. Additionally, despite the fact that daily life and ecology were the focus of the lesson-planning prompt, in their post-implementation responses, 24% of teachers never mention daily life or human impact and another 21% of teachers never mention ecological function, the lowest level in the conceptual model.

Responses to Question 2: Describe an example of how you directly teach about daily life and human impact in a typical food web lesson?

Analysis of the teacher initial lesson plan reports and subsequent modifications (N=32) to the question, "Describe an example of how you directly teach about daily life and human impact in a typical food web lesson?" showed a similar pattern for how teachers connect daily life and human impact to the specific ecological topic of food webs. Responses were tallied for the presence of parameters shown in Table 3.

Table 2. Themes Mentioned by Teachers in their Responses to How They Integrate Daily Life Impacts on the Environment into the Ecology Section of their Curriculum

Themes	Pre-PD Themes	Post-implementation Additional Themes
The Impact of Daily Life Themes	1. Fossil fuel use (10) 2. Recycling/trash (10) 3. Salt (1) 4. Sewage (1) 5. Water use (1)	1. Salt (15) 2. Travel and roads for travel (7) 3. Water in home/NYC drinking water (4) 4. Artificial light at night (3) 5. Recycle/trash/plastic (3) 6. Food (1) 7. Fossil fuel use (1) 8. Sewage (1) 9. Urban heat island (1)
Ecology Themes	1. Food chain/web/pyramid (5) 2. Carbon cycle (3) 3. Ecosystem (3) 4. Materials cycle (2) 5. Biodiversity (1) 6. Habitat (1) 7. Populations (1) 8. Nutrition (1)	1. Abiotic and biotic factors (10) 2. Habitat (6) 3. Water cycle/runoff (4) 4. Genetic diversity (3) 5. Food webs (2) 6. Populations (2) 7. Biodiversity (1) 8. Evolution (1)
Human Impact Themes	1. BP oil spill and oil impacts (6) 2. Climate change (5) 3. Pollution (4) 4. Overhunting/fishing (2) 5. Biodiversity loss (1) 6. Biomagnification (1) 7. Fish kills (1) 8. Habitat destruction (2) 9. Pesticides cause some species to breed out of control (1)	1. Habitat fragmentation/loss (9) 2. Impact of changing abiotic factors on biotic factors, biodiversity, and ecosystems (8) 3. Water, soil, air pollution (6) 4. Impact of salt (5) 5. Inbreeding sheep (4) 6. Urban heat island effect (3) 7. Climate change (2) 8. Erosion impacts (2) 9. Invasives (1) 10. Light pollution (1) 11. Overhunting (1) 12. Seabirds and plastics (1)

Note. Some teachers included more than one theme in their response and themes are organized in descending order from most to least common with the (#) indicating how many times the theme is mentioned.

Closely framing this question around one specific ecological topic (food webs) led almost all teachers to incorporate this topic or the closely related topic of food chains in their responses, unlike teacher responses to the previous question asking about their general ecology lessons, where slightly more than 50% of teachers did not mention any ecological topic in their response (Tables 1 and 3). Responses to this prompt were also more focused than responses to the previous general ecology question. Over 50% of teachers connected human impact to food webs or food chains in their initial response and 44% of teachers connected daily life to food webs or food chains. Yet, almost a full third of teachers specifically stated that they do not connect daily life to food webs and almost all of the teachers who connected daily life to food webs or food chains initially focused only on the ways “people are part of the food web” or food chain.

Table 3. Percent of Pre and Post Responses (N=32) that Mention or Connect Daily Life, Human Impact or Ecology Themes in a Typical Food Web Lesson

	Mention Food Webs	Mention Human Impact	Connect Daily Life Experience to Food Webs (including daily life impact on food webs)	A. Connect Impact of Daily Life Action to Food Webs (part 1 & 2)	B.[a] Connect Only Daily Life Actions to Human Impact (part 1 only)	C.[a] Connect Only the Impact of Human Action to Ecology (part 2 only)	Connect the components of daily life impacts to food webs (summation of columns A, B, & C)
Pre Implementation	97%	72%*	44%	9%	0%	53%	62%
Post implementation	100%	94%*	78%*	59%*	0%*	19%	78%

***** indicates post values are significantly higher than pre values at p=0.05.
[a] column B and C comparisons take the part 1 and part 2 connections made in column A into account when calculating pre-post differences (e.g. post implementation part 1 connections were made 59% of the time as compared to 9% of the time pre implementation).

Very few teachers focused on how daily life impacts food webs or food chains in their initial responses. Post implementation responses show growth in both categories. Almost 80% of teachers connected human impact to food webs or food chains post implementation and almost 60% of these teachers incorporated the impacts of daily life on food webs or food chains in their responses.

The most common daily life pre implementation response focused more on how people are dependent upon the energy in the food web or food chain than on how people impact the food web or chain and these examples tended to focus exclusively on domestic animals or plants that are removed from natural ecosystems (Table 4). Post implementation teacher responses expanded to include many of the ways daily life impacts food webs or chains, and as in previous question responses, used many module examples like roads for travel, salt, and human population growth in Arizona to illustrate how daily life impacts natural food webs or chains.

Biomagnification was a common topic that teachers used in their initial responses to connect human impact to ecology (Table 4). A typical response about bioaccumulation, described "how pesticide accumulates and is transferred up the food chain." Other more creative ways teachers connected human impact to food webs is illustrated by this response:

> We read about the wood thrush, a bird whose habitat has been affected by acid rain in several parts of the country and we write about ways that the food web in these areas will change if the wood thrush population declines.

These responses show that teachers were more successful at connecting human environmental impact to food webs, than they were at connecting human environmental impact to an unspecified ecological concept as solicited in question one. Pre-implementation, a full 62% of teachers identified either level 2 or level 3 pyramid relationships of the *Ecology Disrupted* model in the food web responses, whereas only 31% of teachers identified these relationships in their pre-implementation responses to the generalized ecology question (Tables 1, 3 and Figure 1).

Table 4. Themes Mentioned by Teachers in their Responses to How They Integrate Daily Life and Human Impact into their Food web Lessons

Themes	Pre-PD responses	Post PD and post implementation responses (additional themes)
Daily Life Themes	1. Humans are consumers (9) 2. Local food webs (3) 3. Lifting a black bear hunting ban in NJ (1) 4. Roads and homes (1)	1. Roads for travel (8) 2. Salt (7) 3. Fishing (1) 4. Groceries (1) 5. Human population growth in Arizona (1) 6. Light pollution (1) 7. Littering (1) 8. Urban heat island (1)
Human Impact Themes	1. Habitat destruction/deforestation (9) 2. Bioaccumulation (8) 3. Overhunting/fishing (8) 4. Pollution (4) 5. Acid rain (3) 5. Habitat Fragmentation (1) 6. Invasives (3) 7. Oil spill (1) 8. Population Growth (1)	1. Geographic Isolation (6) 2. Habitat fragmentation (6) 3. Salt and Water Quality (6) 4. Bioaccumulation (5) 5. Invasives (5) 6. Pollution, oil & toxic chemicals (4) 7. Air pollution (1) 8. Littering (1) 9. Population Growth (1)

Note. Some teachers included more than one theme in their response and themes are organized in descending order from most to least common with the (#) indicating how many times the theme is mentioned.

Post implementation teacher responses to the food web question expanded to include many other ways people impact food webs (table 4). This teacher who in his initial response described the impact of biomagnification on food chains, expanded his response to include the daily life impact on food webs. He also brought a module topic, roads, into his post implementation lesson plan response.

> We could say that certain organisms in the food web have been isolated from the others because of the roads humans build. How would these roads affect organisms in the food web?

This teacher response also illustrates some of the weaknesses of post implementation lesson plan responses. Many teachers did not try to connect their initial topic like biomagnification to daily life, but instead chose a new topic to connect to daily life.

Responses to Question 3: Describe an example of how you directly teach about ecological concepts, daily life, and scientific data about human impact into a typical lesson on pollution?

Analysis of the teacher initial lesson plan reports and subsequent modifications (N=35) to the question, “Describe an example of how you directly teach about ecological concepts, daily life, and scientific data about human impact into a typical lesson on pollution?" showed a similar pattern of teacher growth at connecting daily life, human impact, and ecological function in their lesson plan reports. Responses were tallied for the presence of parameters shown in Table 5.

Most of the teachers in their initial responses to this question, mention all the topics that are the focus of this question. Post implementation, they improve their mention of these topics that are the focus of this question, although they are least successful at mentioning ecology (51% and 62% pre and post implementation). Teachers were most successful with their ability to describe the higher-level (top two pyramid levels in figure 1) relationships of the conceptual model - the connection between daily life and pollution, between pollution and ecological function, and daily life and ecological function. Pre-implementation 86% of teachers described at least one connection between daily life, pollution, and ecology. Post implementation most of the teachers (94%) did so.

Table 5. Percent of Pre and Post Responses (N=35) That Mention or Connect Daily Life, Human Impact, or Ecology Themes in a Typical Lesson on Pollution

	Mention Ecology Topic	Mention Pollution	Mention Daily Life	A. Connect Daily Life Impact of Pollution to Ecology (part 1 & 2)	B. [a] Connect Only Daily Life Actions to Pollution (part 1 only)	C. [a] Connect Pollution to Ecological Function (part 2 only)	Connect the components of daily life impacts to ecological function (summation of columns A, B, & C)
Pre Implementation	51%	86%	75%	9%	51%	26%	86%
Post implementation	62%	94%	95%	43%*	37%*	14%*	94%

* indicates post values are significantly higher than pre values at p=0.05

[a] column B and C comparisons take the part 1 and part 2 connections made in column A into account when calculating pre-post differences (e.g. post implementation part 1 connections were made 80% of the time as compared to 60% of the time pre implementation)

Chi-square comparisons of teacher responses to all three questions indicate that teachers may have found connecting daily life to pollution easier than connecting daily life to ecological function. Chi-square tests ($p<0.05$) indicate that significantly more teachers mentioned daily life in the pre and post implementation responses to the pollution question than they did for their pre and post implementation responses to the two ecology questions (general ecology and food webs). Additionally, the same patterns holds for the ability of teachers to identify the higher order relationships between ecology, daily life, and human impact in their question responses. Teachers identified significantly ($p<0.05$) more higher order relationships between daily life, ecology and human impact in their pre and post-implementation responses to the pollution question than they did for the two ecology questions. See tables 1, 3, and 5 to compare teacher responses to the different questions.

Lesson Logs, "What Worked and Didn't" Surveys, and Focus Group Comments

Analysis of teacher feedback on the curriculum intervention shows that many teachers found the *Ecology Disrupted* conceptual model an effective teaching strategy. Half of the teachers who used the curriculum identified the final *Ecology Disrupted* session, the lesson that most overtly linked daily life and human impact to ecological function, as being a curricular element that "worked best," while only 5% of teachers identified a component of these sessions as "working least well."

Focus group comments elaborate on why some teachers found this approach valuable as a conceptual model for teaching the relationship between daily life, human impact, and ecology. This teacher focused on the importance of the relationship between daily life and environmental impact:

> This was probably my favorite part out of everything. I loved this . . . I liked the fact that not only were we looking at the impact, but why is it? Why are we creating these artificial services? Why are we littering in the XXXX River? So that they could see how their actions have consequences.

These teachers focused on the importance of emphasizing the relationship between environmental impact and ecological function.

> I liked how the unit was structured where you had the sort of in-depth look at one issue . . . and then all these other little issues . . . like the winter roads and then the heat island effect, so it kind of left you with the impression that we've learned about humans impacting abiotic factors in this context in depth and it leaves you with this impression there must be a whole bunch of other little stories like this out there . . . I don't think I've stressed . . . that language before where the environmental impact is about humans changing abiotic factors in the environment that impact biotic factors. I thought that was really smooth and well-done and I think that came across really, really well.
>
> It became language we were speaking by the end of the units. . . I never really used that specific language. I mean I would teach them abiotic vs biotic, never those connections; cause and effect.

And this teacher focused on the importance of this conceptual approach for increasing student understanding of these topics as shown by scores on the Statewide biology exam:

> I want to echo that because it was also my favorite part, but I think the real indicators to whether or not they appreciated it is that they actually wrote answers that were applicable on the [Statewide biology exam] from the unit.

Conclusion

Initial Teacher Responses

Initial teacher responses to lesson planning questions show the difficulty of overtly connecting daily life and human environmental impact to ecological function. When asked to describe how daily life impacts ecology, most teachers did not connect daily life and human impact to ecological function in their initial responses (Table 1). Instead, teachers defaulted to individually describing daily life, human impact, or ecological function. Few teachers linked these concepts together to build understanding of how each concept is related and to reciprocally inform understanding of all three concepts. Teacher responses to the question asking them to link daily life and human impact to food webs show a similar pattern, although more teachers successfully linked human impact to food web or food chain function (Table 3). Given a choice, teachers were more comfortable linking daily life experience to food webs, rather than linking the *impact* of daily life to food webs or chains.

Analysis of initial teacher responses may be limited by the tendency of teachers to use shorthand to describe their lessons. Teachers were asked to elaborate on unclear initial responses in an effort to limit this bias. Teacher initial responses were also significantly longer than combined post workshop and post implementation responses. Initial responses may also have been affected by a tendency to understand daily life impacts and human impacts as interchangeable concepts and by a predisposition to view environmental impact as an identical concept to ecological impact. This interpretation is supported by the fact that teachers reported human impact examples in place of daily life impact examples in their initial responses to questions asking about their daily life impacts on ecology and by the high levels of human impact integration that teachers self-reported in their ecology section of their curriculum that were not borne out in their ecology lesson plan descriptions (Figure 2; Table 1). Regardless of the cause for initial teacher difficulty in explicitly linking ecological function to daily life and human impact, imprecise language hindered their ability to use these three concepts to inform one another.

Chi square comparisons of teacher responses to the different lesson planning questions show that linking daily life to human impact is easier than linking daily life to ecological function, as significantly more teachers mentioned daily life in the pre and post implementation responses to the pollution question than they did for their pre and post implementation responses to the two ecology questions (general ecology and food webs). Additionally, significantly more teachers were able to identify higher order relationships between daily life, ecology and human impact in their pre and post-implementation responses to the pollution question than they did for the two ecology questions. These findings are also supported by the significantly higher levels of integration of ecology into their human impact curriculum that teachers self-reported than the level of integration for human impact into their ecology curriculum that teachers reported (Figure 2).

Importantly, teacher initial lesson plan responses indicate that teachers show a greater difficulty integrating daily life and human impact into ecological topics than they do in integrating daily life and ecology into human impact topics. As a result, ecological topics are more likely to be viewed as disconnected from daily life than human environmental impact topics. Lesson plan responses also show that teachers further distance daily life from ecological function by discussing human environmental impact in place of discussing daily life impacts.

Teacher Growth

The ability of teachers to connect human impact and daily life to ecological function grew through using this curriculum. Post implementation, most teachers changed their lessons to add daily life impacts, human environmental impact topics, or additional ecological functions to their lessons and almost 70% of all teachers modified their initial typical ecology lessons to connect daily life to human environmental impact or to connect daily life impacts or human environmental impacts to ecological function (Table 1). More teachers successfully modified their food web or chain lessons (Table 3). After implementation, almost every teacher modified their food web or food chain lesson plans to connect human environmental impact to food web or chain function and just under half of all teachers' post-implementation responses also connected daily life impacts to food web or chain function. Perhaps teachers found lesson plan reporting to be easier for a predefined topic like food webs than they did for reporting of "typical" unspecified ecological lesson plans. Food webs or chains might also be particularly suitable topics for making daily life and human impact connections due to the centrality of human impact themes like biomagnification in the state mandated ninth grade biology curriculum.

Post implementation most teachers showed growth in their ability to make relational connections (the mid and upper levels of the Figure 1 pyramid) between daily life, human environmental impact, and ecological function, but some teachers were still confined to simply identifying the lowest level of the figure 1 pyramid; daily life, human environmental impact, ecological function. Almost all teachers in their responses to the pollution question made high-level daily life and ecology connections, but fewer than a third of the eachers were able to identify the high-level connections (daily life and human environmental impact) in their responses to the general ecology and food web questions.

These teachers, who did not connect daily life and human environmental impact to ecological function, highlight the difficulty of making these complex connections between people and ecology. Many other researchers documented this same phenomenon in their studies of student and teacher perceptions of the concept, "environment" (Loughland, Reid, & Petocz, 2002; Shepardson et al., 2007; Moseley, Desjean-Perrotta, & Utley, 2010). Like these studies, that showed that both students and teachers view people as absent or disconnected from the environment, this study also shows the difficulty that teachers have at articulating a relationship between people and the complex ecological interactions that comprise the "environment."

Findings from others and from this study suggest that these connections may, by their very nature, be difficult to articulate ((Loughland, Reid, & Petocz, 2002; Flogaitis & Agelidou, 2003; Shepardson et al., 2007; Moseley, Desjean-Perrotta, & Utley, 2010). Despite the fact that study participants were highly educated and qualified, some teachers did not describe any higher order relationships between people and ecological function when explaining how they teach ecological topics, even after participating in this extensive professional development program. Reaching these teachers would most likely require more personalized training and greater exploration of teacher mental models prior to encountering the *Ecology Disrupted* curriculum. Yet, impacting these teachers is particularly important, for a primary goal of this curriculum is to improve student learning of ecological function and how it connects to daily life and human environmental impact. Without teacher understanding of the *Ecology Disrupted* conceptual model, this curriculum will be unlikely to help student learning.

This study documented the difficulty of applying a conceptual model that overtly connects daily life and human environmental impact to ecological function. Despite this, the implementation by teachers of curriculum grounded in the *Ecology Disrupted* conceptual model helped them articulate that model. In the words of the teachers who implemented this curriculum, making the connections between daily life, human environmental impact and ecological function allowed their students to see that "their actions have consequences" and brought to their classrooms an ecological "lens" and "language" for understanding "environmental impact."

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Appendix 1. Survey Questions

To what degree do you integrate content about HUMAN IMPACT into your lesson planning for the ECOLOGY section of the Biology curriculum?

[1]	*[2]*	*[3]*	*[4]*	*[5]*
Not at all; I teach them separately		*Somewhat*		*The content is entirely integrated*

To what degree do you integrate content about ECOLOGY into your lesson planning for the HUMAN IMPACT section of the Biology curriculum?

[1]	*[2]*	*[3]*	*[4]*	*[5]*
Not at all; I teach them separately		*Somewhat*		*The content is entirely integrated*

Personally, how important do you think it is to integrate content about HUMAN IMPACT into ECOLOGY lessons?

[1]	*[2]*	*[3]*	*[4]*	*[5]*
Not at all important		*somewhat important*		*very*

Personally, how important do you think it is to integrate content about ECOLOGY into HUMAN IMPACT lessons?

[1]	*[2]*	*[3]*	*[4]*	*[5]*
Not at all important		*somewhat important*		*very*

Appendix 2. Terms Used to Identify Ecology, Daily Life Impact, Human Impact

Ecology [derived from McComas (2002)]

1. Abiotic/Biotic factors
2. Bioaccumulation/Biomagnification
3. Biomes
4. Communities
5. Cycling of materials (water, nitrogen, carbon)
6. Ecological succession (including climax community)
7. Ecosystems
8. Energy pyramid
9. Evolution
10. Food webs/chains
11. Genetic diversity
12. Habitat
13. Limited resources/competition
14. Niche
15. Populations
16. Predator/Prey/Symbiosis
17. Runoff
18. Trophic Levels

Examples of Daily life impact and Human impact:

Daily Life Impact

1. Artificial light in homes
2. Buildings/Development (our homes)
3. Drinking water
4. Driving (cars)
5. Fossil fuel use
6. Food – i.e. eating, grocery stores, specific food we eat (like fish)
7. Impact on local areas (i.e. parks, bear hunting)
8. Roads on which we travel
9. Salting roads
10. Sewage (local)
11. Trash (littering; non-biodegradable products, packaging, plastic, recycling)
12. Urban sprawl

Human Impact

1. All the impacts from daily life described
2. Biodiversity loss
3. Biomagnification/Bioaccumulation
4. Climate change
5. Deforestation
6. Eutrophication
7. Extinction

8. Genetic diversity/inbreeding
9. Habitat fragmentation/loss
10. Impact of biota of changing abiotic factors
11. Invasives
12. Overharvesting
13. Human population growth
14. Pollution (acid rain, air, soil, light, nutrient, oil, pesticides, etc.)
15. Urban heat island effec