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Environmental Topics in Physics by Inquiry Course: Integration Models Used by Physics Teachers

David A. Kimori
Minnesota State University, Mankato, david.kimori@mnsu.edu

Gillian Roehrig
University of Minnesota, roehr013@umn.edu

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Abstract

As we approach the second quarter of the twenty-first century, one may predict the environment will be among the dominant themes in political and educational discourse. This study investigates how three physics teachers integrated environmental topics and issues in their classroom. Data collection methods including field notes taken from observations, teachers' interviews, and a collection of artifacts and documents were used. The data were coded, analyzed, and organized into categories utilizing Fogarty's models of curriculum integration. Findings of this study indicate teachers acknowledge the importance of teaching environmental issues in their classrooms; however, implementing and utilizing effective integration strategies and models continues to present a challenge.

Keywords

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David A. Kimori
Minnesota State University, Mankato, Minnesota, USA

Gillian Roehrig
University of Minnesota, Minnesota, USA

As we approach the second quarter of the twenty-first century, one may predict the environment will be among the dominant themes in political and educational discourse. This study investigates how three physics teachers integrated environmental topics and issues in their classroom. Data collection methods including field notes taken from observations, teachers' interviews, and a collection of artifacts and documents were used. The data were coded, analyzed, and organized into categories utilizing Fogarty's models of curriculum integration. Findings of this study indicate teachers acknowledge the importance of teaching environmental issues in their classrooms; however, implementing and utilizing effective integration strategies and models continues to present a challenge.

Keywords: environmental topics, physics, curriculum integration, physics teachers, multiple case study

Over the past three decades, particular perspectives regarding the environment have begun to emerge: (a) realization by human beings that we not only live on Earth and use its resources at an increasingly high rate but we also actually belong to the Earth and the total ecology of all living systems, (b) there are strong interactions among different components of the large and complex systems that make up our environment, and (c) the rising human population and its impact on the environment is a great concern (Hughes & Mason, 2014). Studies have revealed that although students do not have a deep understanding of environmental issues and lack environmental awareness and attitudes necessary for protecting the environment, they have great concern for the environment (Chapman & Sharma, 2001; Fien, Yencken, & Sykes, 2002). However, addressing environmental issues in the classroom and other disciplines has never been an easy job for teachers (Edelson, 2007; Pennock & Bardwell, 1994).

Addressing environmental issues in the classroom has been difficult because of limited teacher knowledge or interest, unreceptive institutional cultures, and a lack of state requirements and national accreditation (Ashmann, 2010; Powers, 2004). Among the various subjects taught in secondary schools, science is often perceived as one that can make a significant contribution to environmental education (Chi-Chung Ko & Chi-Kin Lee, 2003). Investigating real-world environmental issues motivates learners by making learning relevant, as well as helping students to practice and develop skills such as decision making, critical thinking, and problem solving (Pennock & Bardwell, 1994). Integration of environmental issues in physics will not only increase students' interest in physics (Pratte, 2006) but also provide them with skills they can use in resolving a range of societal issues as citizens. Some scholars have suggested environmental education offers science education a range of perspectives on knowledge and situated learning while at the same time challenging current, orthodox thinking in the subject (Dillon & Scott, 2002).

Introducing Environmental Issues in the Physics Curriculum

Introducing environmental issues in the physics curriculum can help students understand the relevance of physics topics, such as energy and electricity (Osowiecki, 2011). Integrating environmental issues in physics not only promotes production of active citizens but also improves engagement and interest in physics. For example, Pratte (2006) found incorporating environmental modules in physics increased a third of his students' desire to take another science class while another quarter of the students expressed an increased interest to teach science. Today, interdisciplinarity is more the norm than the exception in universities, and the notion of a physics course has broadened somewhat (Moll & Kotlicki 2010). Despite this fact, the number of examples of environmentally relevant physics curricula for science majors in recent literature remains low (Pratte, 2006). Thus, there is a need to research effective ways through which physics teachers integrate (or can integrate) environmental issues in their curriculum.

Curriculum Integration

Advocates of curriculum integration have outlined several models for implementation. Placing models on a curriculum continuum reveals they range from traditional discipline-based, objective driven, and teacher-controlled models to interest-based and student exploration-driven models (Kysilka, 1998). Many authors have presented models of curriculum integration in an attempt to explain the various stages of integration design and how to "blend" curricula. For example, Fogarty (1991) identified ten models of curriculum integration ranging from the fragmented (traditional) disciplines approach to a completely networked approach to curriculum planning. Fogarty's models are more focused on the "how" rather than the organizational structure of the curriculum (Figure 1, see Appendix A). Fogarty categorized integration using ten models: fragmented, connected, nested, sequenced, shared, webbed, threaded, integrated, immersed, and networked models. The models are further categorized into those that integrate curriculum within a single discipline (the fragmented, connected, and nested models); those that integrate curriculum across disciplines (the sequenced, shared, webbed, threaded, and integrated models) and then those that integrate curriculum within and across learners (the immersed and networked models). Fogarty's categorization of integrated curricula was used as a framework to explore the ways in which physics teachers integrated environmental issues into their physics instruction and reveal which model of integration they used, if any, because it provides an opportunity to observe different levels of integration from integrating within a discipline, across disciplines and across learners. According to Forgaty, integration across learners is more advanced, followed by across disciplines and then within disciplines; therefore, this framework would reveal various levels of integration among the teachers.

Statement of the Problem

The environmental challenges confronting the world today require active participation by all citizens. There is an increasingly urgent need to develop a culture of participation among young people who in turn may become future leaders. Finding ways to engage youth as full participants and leaders in environmental initiatives is critical to ensuring a more sustainable future (Gwekwerere, 2014) as "our communities will only reach their potential as vibrant and healthy places when youth are welcomed as full participating members" (Warner et al., 2010, p. 95). Environmental problems cannot be addressed comprehensively by looking through the limited lens of only one of the traditional disciplines established in academia (Dzelalija, 2004; Saundry, 2011). Research in the field of Earth Systems Science suggests that we need to find appropriate ways to integrate high-quality disciplinary work from several fields (Hughes & Mason, 2014). Thus, this study seeks to investigate how physics teachers can and do integrate environmental issues in a high school physics course.

Specifically, this study considers how high school physics teachers integrate environmental issues into a Physics by Inquiry course. The research questions that guided this study were:

> How do physics teachers integrate environmental issues in a Physics by Inquiry course? Specifically: (a) what integration models do physics teachers employ in integrating environmental topics/issues in their instruction? (b) What are the Physics teachers' perceptions of integrating environmental issues in their classroom?

Research Context

Physics by Inquiry is a college-level course taught in high schools through a concurrent enrollment program called the College in the Schools (CIS). CIS is a nationally accredited program that brings a faculty member from a large midwestern university together with high school teachers to offer university courses in high schools. The main goals of Physics by Inquiry courses are to help students (1) develop an understanding of some fundamental concepts in physics by working in ways similar to scientists, (2) use those physics concepts to understand environmental issues and develop solutions to environmental problems, and (3) develop skills for scientific argumentation (i.e., justifying a claim with evidence).

The specific environmental themes were determined by the university's lead instructor, and materials such as PowerPoints, videos and reading articles were provided to the teachers. There were four broad environmental topics, each associated with a physics unit. Table 1 summarizes the physics topics, environmental themes, and key environmental questions investigated in the Physics by Inquiry course.

Table 1
Environmental Themes: Key Environmental Questions and Physics Topics Taught Together

Physics Topics	Environmental Themes	Key Environmental questions explored
Electric Circuits	Energy generation	How is electricity generated? In what way do these processes affect the environment? How can these impacts be minimized? What are the policies surrounding the production and distribution of energy?
Light and Optics	Light Pollution	What is light pollution and how does it impact the environment? What are the effects of light pollution on individual animals and on ecosystems? What are emerging technological solutions?

Light and Color	Solar Energy	How do we get usable energy from the sun? What are the practical and technological limits of solar energy? What are the advantages and disadvantages of solar energy compared to other energy sources? How does policy support the adoption or non-adoption of solar energy?
Astronomy by Sight	Climate Change and Scientific proof	What constitutes scientific proof? What are the indicators and evidence behind claims of global climate change? How are standards of scientific proof applied in investigations of incidents of harmful pollution? In what ways is public policy around climate change and pollution consistent or not consistent with standards of scientific proof?

Researcher Positionality

The first author of this study had previously taught the Physics by Inquiry course through the same CIS program. Thus, he was known to the participants in this study and had access to inside information about the course and CIS program. As such, the researcher's own bias might have affected data collected and its 6nvironm. Furthermore, the researcher's presence in the classrooms could have been interpreted as an evaluative role as the teachers were aware of the researcher's previous role in the same course; thus, they could have changed how they typically taught in other days.

Method

We utilized multiple case study approach in this study to determine how physics teachers integrated environmental issues in their curriculum. Yin (2003) defines case studies as a qualitative research method where: "a how or why or what question is being asked about a contemporary set of events, over which the investigator has little or no control" (p. 9). The case study methodology was employed because it allowed for detailed understanding of the integration of environmental topics within the context of three physics classrooms. In this study each individual case represents a single physics teacher teaching the Physics by Inquiry course.

Participants

Three physics teachers, Allison, John, and Paul (all pseudonyms) were selected for this study through a purposeful sampling technique to form information rich cases (Patton, 2002). The selection of participants was based on their willingness to participate, the physics topics they were teaching, and integration of environmental impacts in these topics. A total of eleven teachers were asked to participate, but only three were willing to participate. A non-interventionist approach was preferred since the research aimed to focus on current practice rather than on a limiting view of "ideal" practice; therefore, it was necessary to find classrooms where environmental issues were already being taught. The three teachers included two males and one female; their teaching experience ranged from 15 years to 18 years with an average of 16.7 years. Two of the teachers taught in suburban school districts and one taught in an innercity school district. Institutional Review Board approval was obtained for this study. Informed consent was obtained in writing from all participants and from the school administration where the teacher was employed.

Data Collection

The data collected for this study were intended to provide a rich description of three different cases where environmental topics were being integrated into the Physics by Inquiry course. The three cases were studied over a period of two semesters that involved observing a series of lessons, in which they integrated environmental topics and conducting semi-structured interviews within each case to gain a deeper understanding of the relationship between teachers' perceptions and experiences (Yin, 2003).

Classroom observations, semi structured interviews, and curriculum documents and materials such as lesson plans and worksheets were the major sources of data. Three observations were carried out for each teacher over the course of the semester (three months), and each lesson observed was about 55 minutes long. The decision on which lessons to observe was determined by the teachers based on days they were working on environmental topics. During observations, field notes were taken and the lessons were audio recorded using a lapel microphone worn by the teacher. Recordings helped in capturing and clarifying some information that might have been missed in the field notes.

The semi-structured interviews were completed with each teacher after the final classroom observation. The semi structured interview prompted the teachers to discuss self-reported experiences on role of integrating environmental topics in physics, and the interview prompted them to draw on the challenges they faced while integrating environmental issues in their class. Furthermore, the interviews were used to learn the teachers' experience in integration of environmental topics and if the integration impacted the students' approach in learning physics and their perspective on the environment. Interviews were approximately 40 minutes in length. Each interview was audio recorded and transcribed for analysis.

Data Analysis

Once all the data were collected, they were prepared for the analysis process. All the audio-recorded interviews were transcribed. All the observational and interview data, including scanned curriculum and classroom handouts, were organized into case files. A summary of the alignment of data sources with the research questions and approaches to data analysis are shown in Table 2 below:

Table 2
Research Questions: Data Sources and Analysis Strategies

Research Question Strategies	**Data Sources**	**Analysis**
a) What integration models do physics teachers employ in integrating environmental topics/issues in their instruction?	Curriculum materials, classroom observations and audiotape for lessons Semi structured interviews	1. Reading and reading field notes relevant data. 2. Clustering similar categories together according to Fogarty's 10 models.

b) What are the Physics teachers' perceptions of integrating environmental issues in their classroom?		3. Condensing categories assigning them into codes. 4. Reading and reading the interview transcripts. 5. Annotating interview transcripts. 6. Creating data subcategories and categories 7. Connecting categories to come up with themes

In this multiple case study design, a deductive approach was used to analyze the data and then a cross-case analysis was conducted (Miles & Huberman, 1994). This process was used to create meanings from complex data through emerging categories and themes and to complete cross-case analysis (Miles & Huberman, 1994). First, observational data sources were coded using the ten models of curriculum integration (Fogarty, 1991) to determine which integration approaches teachers used in the integration of environmental issues and physics (see Figure 1 in Appendix A). Field notes and curriculum materials were read and re-read, then highlighted and tagged with the ten integration model codes. Tagged and coded field notes and curriculum materials were used to identify statements, episodes, and activities that represented different integration approaches during a lesson. Next, we clustered the integration codes into broader categories guided by the main groupings proposed by Fogarty (1991; see Figure 1 in Appendix A). Three categories were identified: (1) WSD-within single discipline, (2) AD-across disciplines, and (3) WAL- within and across learners. In WSD we included fragmented, connected, and nested; in AD we included shared model, while in WAL we included immersed and networked models.

Table 3
Categories of Integration Observed in Participants' Classrooms

Category*	Criteria and explanation
WSD	This code indicated that integration occurred within one single subject area.
AD	This code indicated that that integration occurred across two or more subject areas.
WAL	This code was used when one or both of the following criteria was met: • Integration occurred within learners themselves. • Integration occurred across network of learners.

Notes. WSD = within single discipline; AD = across disciplines; WAL = within and across learners

WSD incorporated statements from both interviews and observation notes or activities that indicated there was integration within environmental topics or physics. Within this category, the teacher discussed or was observed making deliberate efforts to relate ideas/strands within a discipline rather than assuming students would automatically understand the relationships within the instructional setting. AD incorporated statements that indicated linkage of content from different disciplines. Within this category, teachers were observed or indicated re-organizing what was taught and assisting students in making meaningful connections between physics and environmental topics. Lastly, statements or activities within the WAL category needed to meet one of two criteria or both in order to be coded as WAL (Table 3): (a) integration occurred within learners themselves (i.e., the learner is in control of the knowledge learned, the strategies used, and the sharing of that knowledge with other students), and (b) integration occurred across network of learners (i.e., learners are pro-active in the learning process and initiate their own searches for information, skills and concepts, relying on experts and other learners as resources for their own learning).

To address the second research question, interviews were transcribed and then uploaded to a computer program NVivo10. We read through the interview transcripts while annotating relevant phrases and sentences using NVivo10 to denote statements that could answer our second research question to learn how the teachers perceived the integration of environmental issues in their classrooms. We created sub-categories by grouping the annotations, then we looked into connections among these sub-categories, and we came up with major categories for our analysis and cross-analysis.

Case Analysis and Results

Case I-Allison

Allison has taught for 17 years at a suburban high school. She has taught chemistry and physics, including a College in the Schools (CIS) physics course for 3 years. This was Allison's second year integrating environmental issues into the CIS physics course. Allison has a strong background in environmental education, with a master's degree in environmental engineering and a certificate in environmental education. She also has experience teaching chemistry and incorporating environmental education in chemistry.

Allison's Perceptions of Environmental Integration

Allison asserted the environmental topics were a vehicle to help students make connections between their experiences and physics, as well as a way to increase student interest in physics and provide them an opportunity to make connections to real life. She said that these real-life connections allowed students to engage in robust discussions on matters relating to the environment:

> I really like that it [environmental topics] makes a connection between the physics they are learning and probably more of the popular science that will be useful as they make decisions in their lives say voting decisions or personal choices or those kind of things.

She also mentioned that the most important aspect of the environmental issues in physics was that it has led to students making lifestyle changes in terms of decision-making.

Allison's Implementation of Environmental Issues

Allison taught a unit on electricity and circuits that incorporated environmental issues related to electricity and energy sources. Students worked in small groups on inquiry-based activities throughout the physics only portions of the unit. Once a week, Allison added environmental connections through a class-led discussion that involved all students and sometimes incorporated a demonstration or small group work. The first environmental lesson was about fossil fuels and carbon dioxide reduction using renewable energy sources. In this discussion she focused on burning coal, disposal of the ash byproduct, and the effects fossil fuels have on the local population. For the discussion on renewable energy sources, she talked about nuclear and solar power, including connections to the physics content. During the second lesson, she focused on environmental impacts of electricity generation and greenhouse gases, such as carbon dioxide, methane, nitrous oxide, and chloral floral carbons (CFCs) and their impact on global warming. During the third lesson, students picked different topics on electricity to research in small groups and present to the class.

To incorporate environmental issues in her class, Allison applied various integration models throughout her teaching. She explained that the first year she did not do much to connect and integrate the environmental issues apart from teaching what was provided by the university instructor. She said:

> I think the only time that I veered away from what, you know, university lead instructor had provided was in particular like last year when we did that lifestyle project and the kids had to choose an environmental topic more relevant in their lifestyles.

However, she realized she needed more background in environmental topics and good strategies to involve students in the learning process just like they did in the lifestyle project where they were involved in something that was more relevant to their lives.

Case II-John

John has taught for 15 years, teaching high school Physics and Biology. This was also his second year 13nvironment environmental issues in CIS Physics. John has a bachelor's degree in ecology, evolution, and behavior, and he has a master's in science education and licensed to teach Physics.

John's Perceptions of Environmental Integration

John described his experience with incorporating environmental topics in physics; he explained the first year he had to get new teaching strategies to engage the students, particularly in this class his new strategies included: mini lectures, open discussions, and debates. John also felt these strategies helped students who were struggling in physics, he said: "I think it kind of lends itself maybe a different to the type of student that would normally be turned off by physics."

John mentioned that integration of environmental topics in physics acted as bridge between physics and what the students can do with it in real life to solve real problems. He said, "In Physics by Inquiry, it's like they learn communications skills, they learn about organization and just general everyday thinking arguments on environment, scientific arguments on the environment and possible solutions on environmental problems." John also mentioned he tried to match environmental topics with the physics concepts he was teaching.

John's Implementation of Environmental Issues

John taught a unit on properties of matter unit and light and optics topics and incorporated environmental issues. John tailored environmental materials and activities to students' interests and the topic being covered; for example, he would hold debates that elicited students' interests in topics like air pollution and how it affects visibility and air quality. John included environmental topics once a week and sometimes twice depending on how much time the activities demanded. For example, in one class period he might have students read and discuss an article, and then have a debate on the same topic the following period and focused on greenhouse gases and discussed the role of carbon dioxide in the greenhouse effect and how to reduce its concentration. In another class period, John focused on conservation of energy and nuclear fusion. He also discussed how science and society affect each other regarding fusion research in another class period.

In going about the integration of environmental issues in his class, John applied various approaches throughout his teaching. John allowed his students to pick environmental topics that they were interested in and debate these topics. John said the debates were just for "breaking up the lab fatigue and giving the students something different to do." On some days, John said he basically gave them a choice of what they wanted to do, like book readings and discussions.

Furthermore, John mentioned trying to base his instruction on students' feedback. He said, "We have done like, create your own project, that's what came out this year, that my students liked." John said this kind of approach has made the students take concepts to a higher level of understanding. He said:

> They really like the Physics by Inquiry, but they thought it wasn't thorough inquiry because they weren't asking the questions. So, we did like a week where they, they took one part and stretched it. They created their own experiment basically and presented it to the class.

Here John was referring to Physics by Inquiry class was not as inquisitive as they expected but incorporating environmental issues motivated them to autonomously explore more knowledge beyond the class expectations.

Case III- Paul

Paul has 18 years of experience teaching high school Physics. He has an undergraduate degree in physical science and a master's of science with a physics emphasis.

Paul's Perceptions of Environmental Integration

Paul described the Physics by Inquiry class as "a very cool way to learn" where he thought students learn well by doing and not from the text. He said:

> This is very much guided inquiry. They [students] can't learn anything from reading the textbook, but where the learning comes in is when they do the experiments that the textbook walks them through ... and the textbook leads them towards those ah-ha moments when they form the correct understanding of physics and overcome their misconceptions.

When Paul was asked what he would do differently going forward he responded, "It is pretty tough to integrate anything the way the curriculum is set. It will make sense if the environmental course was taught separately." Furthermore, Paul said he would love to see environmental science made an elective for all students:

> Make it [environmental science] an elective and teach it separately. I would love to see it added as a required course in high school and that every single student had four years in science starting in ninth grade... physical science, biology, chemistry, physics... and then an environmental science.

John's Implementation of Environmental Issues

Paul taught properties of matter, electricity, and circuits units while incorporating topics related to environmental issues. Paul included environmental topics once a week, and he would normally start with a lecture on environmental topics for the first half of class; then, during the other half of class, the students would work on their Physics by Inquiry labs without any integration of environmental topics.

The environmental topics that Paul taught in his classroom were selected to align with the big physics topics he was teaching. For example, in one class period he talked about environmental impacts and the generation of electricity, which was aligned to the physics topic electricity and circuits. In another class period, he talked about solar energy and solar thermal energy, where he mostly focused on the trends of the use of solar power since the year 2000 and the considerable increase in its use in 2012. In another class period, Paul talked about solar panels and how they work.

Most of the time Paul used guided inquiry to teach physics concepts. When asked how he incorporated environmental topics in his class, Paul said he gave separate lectures on environmental topics and separate assignments and projects.

Paul mentioned integration of environmental topics in physics might lead to students to change their lifestyles and perceptions of the environment. For instance, he believes their small contributions might have a huge impact on the environment. He said, "a small change in their lifestyle could have a pretty big impact in their carbon footprint." Paul mentioned he wanted to assess how many changes the students actually made after learning about the environment to see the impact. He said:

> I often wanted to add some sort of journal question, now late in the year, referring back to that project, and see how many of the changes that they did... they actually made long-term and did a lifestyle change. I would be very interested to see if any of them have changed or if any of them have talked to friends, family, somebody else about the project and if they have been able to influence them and if this is something we can do on a grassroots level to actually make a change.

Paul also taught students that little changes in lifestyle can have a large impact if you get everybody to do them. He believed the students understood how fragile the environment is. He said, "when we look at what's happening in the Arctic, they were very surprised when they did the research and found those things happening."

Paul did not use integration to incorporate environmental topics in his teaching, he said:

> I really didn't integrate the topics. I stopped what I was doing in the inquiry and did the PowerPoint lessons that were developed by the university instructor and

> I had them [students] do their journals. But there was really no connection only little break from what they had been doing with inquiry.

Paul explained that the students sometimes would get tired of inquiry labs and they needed something else and thus the environmental lectures served well as a break.

Cross Case Analysis

Integration Within Single Discipline

All three teachers used the WSD integration in their classrooms, although at different levels: fragmented, nested, and connected. The extent of integration within WSD model could be attributed to each teacher's comfortability and knowledge base to teach environmental topics. Allison and John, who had previous exposure to environmental education and ecology respectively, appeared to bring these experiences and knowledge. Thus, Allison and John were able to show more use of integration within the WSD model compared to Paul.

All three teachers used a physics topic as a context to integrate environmental issues in their teaching clearly displaying the connected model. For example, electricity was used by all teachers as a context to teach physics ideas and environmental issues associated with the generation of electricity like carbon dioxide emission for generating electricity from coal.

For example, in Allison's class when she was talking about clean energy sources, she also related this to the economics of production of clean energy and political issues involved in the production of clean energy as geo-economics and geo-politics, which are other topics of environmental education. Rather than assuming the students would automatically know there are political and economic implications to the production of clean energy, Allison made an effort to point out these connections. Also, while talking about coal ash disposal in areas where people live, Allison noted the people in these areas are mostly people living in poverty. Through these interactions she was able to connect environmental impacts from the generation of electricity to concerns about sustainable development.

The teachers used the connected model to bring real life connections to what they were teaching. The real-life connections that all the teachers in this study made were mostly drawn from their personal experiences, popular media as some of the environmental issues happened when they were young, or from their personal interests; therefore, they could readily use these models in their teaching to make connections to physics or other sciences.

Lastly, the three teachers also implemented Fogarty's nested model in their teaching by integrating the common skills like collecting data, researching on information, analyzing pictorial representations, reading, writing, and critical analysis of a claim, in their physics and environmental topics classes. It was noted that these skills were nested within both physics and environmental topics.

Integration Across Disciplines

Integration across disciplines (AD) was rarely observed with the three participant teachers. When the integration across disciplines approach was used, the teachers "partnered" and planned units to focus on "overlapping ideas." In this model, the shared context all three teachers used was on electricity and energy, which also provided a context to talk about physics principles and environmental issues. For instance, while teaching electricity and circuits in physics, Allison talked about how generation and distribution of electricity was an environmental issue associated with production of greenhouse gases. Allison talked about environmental issues associated with the generation and distribution of electricity contextually linking electricity and circuits in physics and generation of electricity in environmental point of view.

Similarly, John was of the view that integration of environmental topics in physics acted as bridge between physics and what the students could do with physics to solve real problems using the nested model. He said, "In Physics by Inquiry, it's like they learn communication skills, they learn about organization and just general everyday thinking arguments on environment, scientific arguments on the environment and possible solutions on environmental problems." In addition to Physics by Inquiry providing opportunity to connect environmental science with physics in real life contexts, John also acknowledged it provided an opportunity to see relationships in and out of school and for student to practice common skills like communication.

Like Allison, John also integrated physics topics with environmental topics by linking them in the same context. For example, while he was teaching conservation of mass, John also talked about ecological balance and balance within an ecological niche. He said, "I actually did use ecological balance when we talked about mass balance." Conservation of mass is a physics concept that demonstrates to students that mass cannot be destroyed or be created but is conserved while ecological balance involves living organisms preying on each other and reproducing to maintain that balance. The use of ecological balance does not help understanding of the law of conservation of mass, but it addresses the same theme of balance. Similarly, when he talked about uncertainty in physics he also spoke about environmental uncertainty. Uncertainty in physics addresses the plus or minus error in measurements while environmental uncertainty involves not being sure about future weather or climate changes. He stated:

> Environmental uncertainty it seems to fit naturally for example, we don't know exactly how high the waters are going to rise which was one theme in the last lecture I had. And we also don't know how warm it's going to be.

The theme of uncertainty provided John an opportunity to also talk about uncertainty in the environment but not in any way elaborating understanding of uncertainty in Physics or its relationship.

On electricity and circuits from the physics point of view, all the teachers walked students through connection of circuits using wires, a bulb, battery, and switch to make a complete circuit and different types of circuits like parallel and series circuits. Studying circuitry in physics gave students a small-scale picture on how electricity can be transmitted from the power source (battery) to produce required output (light bulb) to the consumers; this provided a linkage to large scale on how production of electricity can have an environmental impact thus linking physics to environment. On a larger scale, students were made aware that some significant sources of electricity, like hydroelectricity and coal, have some environmental impacts associated with them.

Integration Within or Across Learners

Students provide a pivotal role in the within or across learners (WAL) integration model. Only John and Allison used this model in their classroom. They used Fogarty's immersed and networked models. In John's classroom, for instance, it was noted he used the immersed model by using open discussions and debates where learners were deeply immersed in topics that they had interest in. For example, some students would talk about climate change and global warming and other students talked about fusion research. From the interview, John said the students really liked debates and having open discussions especially "the type of student that would normally be turned down by physics." Noting how immersed the students were in their personal interest expertise and interests.

Just like John, Allison used class discussions that allowed students to express ideas they were passionate about by using the networked model. During the interview she said, "I try to make it (i.e., class discussion) a little bit more robust instead of just flipping through PowerPoint slides and going over the information." By a robust discussion, she meant a discussion where learners are engaged as owners of knowledge. Also, Allison had seven questions each on a white board displayed around the classroom and asked her students to read and pick a question that addressed a topic they were most interested in doing research on. Then, in groups, students used the internet and any other resources available to research the topic in depth to obtain a better understanding of it. She also provided the resources for students to utilize in gathering information before sharing with their colleagues as experts.

Discussion

The models of integration used by the three teachers were: fragmented, connected, nested (WSD), shared (AD), immersed, and networked (WAL). In using these models to integrate environmental issues into a physics course the teachers reported students were motivated to engage in physics topics and to autonomously do research and seek more knowledge on environmental issues. This is consistent with (Osowiecki, 2011) assertion that introducing environmental issues in the physics curriculum can help students understand the relevance of physics topics, such as energy and electricity. The same assertion is echoed by (Pennock & Bardwell, 1994) that investigating real-world environmental issues motivates learners by making learning relevant. According to Pratte (2006), incorporating environmental modules in physics increased a third of his students' desire to take another science class while another quarter of the students expressed an increased interest to teach science. Although our aim in this study was to investigate how physics teachers integrated environmental issues in their classes, these results hint that from the introduction of environmental issues students developed a desire to learn more in the field of environmental sciences. This notion is also supported by Edelson (2007) that in a system where environmental sciences were integrated fully into the curriculum, the sense of purpose for learning science would become internalized and might carry over to other courses as well.

Lastly, we found that teachers perceived the integration of environmental issues in physics as a good idea, but they struggled on how best to implement this integration. In particular, they struggled with how to connect physics topics with environmental issues and mostly ended up addressing environmental issues as separate topics on separate days. They indicated that they could benefit from more training on integration models or strategies of teaching.

Implications

The three teachers in this study called for more professional development to improve their knowledge and ability for integrating environmental issues. It has been established that teachers are more likely to produce students who are more environmentally literate if the teachers are more knowledgeable, have positive attitudes towards the environment, and show concern for environmental problems (Tuncer et al., 2009). Thus, one implication from this study is the need for professional development (PD) geared towards integration of environmental education.

Administrators and teacher educators need to empower teachers with the frameworks and strategies to implement environmental topics through integration in school curriculum.

This can help teachers teach environmental topics integration in a more effective way and make them more willing to implement environmental topics integration in their classrooms. In addition, professional development programs and support from all education stakeholders are essential to build environmental science knowledge of teachers so the integration process is smoother and less time consuming during planning and implementation. Teacher educators should develop programs that provide more assistance to teachers on how to incorporate environmental topics in their classrooms.

There is potential for teachers to improve students' chances of applying what they learn to tackle formidable environmental changes. Moreover, this study emphasized the importance of considering what and how to integrate environmental topics in terms of both designing of learning experiences and engaging students in real life experiences with anticipation to create awareness and behavior change as final outcomes. The findings presented here will help others determine how to best integrate environmental topics in a physics curriculum.

Limitations

As a case study with a small number of participants, the findings are not generalizable. In addition, the participants were using materials provided by the faculty lead for the CIS physics course. The nature of these curriculum materials or modifications made to these materials by participants was not analyzed. Further research is necessary to understand the impact of curriculum materials and professional development for physics teachers to integrate environmental issues into their physics classroom. Additionally, as the data was collected in CIS physics classrooms where the teachers have a strong physics background, further study would be needed to understand the nature of environmental integration in regular physics classrooms.

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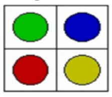
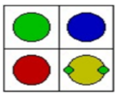
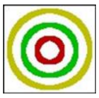
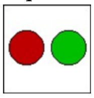
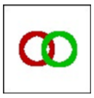
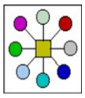
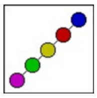
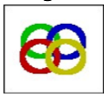
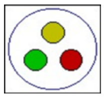
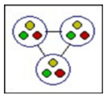
Appendix A

Figure 1
Fogarty's Ten Models of Curriculum Integration

Within a single discipline			**Across disciplines**					**Within and across learners**	
Fragmented 	**Connected** 	**Nested** 	**Sequenced** 	**Shared** 	**Webbed** 	**Threaded** 	**Integrated** 	**Immersed** 	**Networked** 
Focuses on one content area at a time, such as mathematics or science. Students are taught in different classrooms and by different teachers.	Makes explicit connections with each subject area being taught and connects one topic or one skill or further connects the previous week's or semester's work to the next	Emphasizes integrating multiple skills, such as a thinking skill, a social skill, and a mathematics skill, that take place in each subject area	Topics are rearranged and sequenced strategically to provide a broad view that relates concepts.	Brings two disciplines into one focus. This model also focuses on concepts and skills development	A similar conceptual theme is used to provide a common ground for cross-discipline units.	Focus on different skills, such as thinking skills, study skills, technology skills, mathematics skills, and so on that need to be learned	Blends four major disciplines; i.e., math, science, language arts and social studies.	The integration process is highly associated with individual learners' interests, expertise, and experiences.	The integration process is associated with a network of learners' interests, expertise, and experiences.

Author Note

David Kimori is an Assistant Professor of STEM Education at Minnesota State University, Mankato. Please direct correspondence to david.kimori@mnsu.edu.

Gillian Roehrig is a Professor of Science Education and an Associate Director of STEM Education Center at the University of Minnesota. Please direct correspondence to roehr013@umn.edu.

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