



INTEGRATION OF MATHEMATICS AND ENVIRONMENTAL EDUCATION: CHANGE IN THE VIEWS OF 5TH GRADE STUDENTS TOWARD SUSTAINABILITY

Duygu ÖZDEMİR

Abstract: Combining mathematics and environmental issues may be a valuable way not only to increase environmental awareness of students but also provide real life context to the mathematics lessons. In this study, it was aimed to explore changes in the views of 5th grade students toward sustainability with the help of the tasks integrating environmental education and mathematics education contents. Based on this aim, as convenient sample, a fifth-grade classroom in a private school in Tukey selected and students attending to this classroom participated in the study. Environmental education issues and mathematical contents were integrated in students' tasks and these developed tasks were applied as a regular part of the teaching processes of this classroom. Before and after applications, semi structured pre-interviews were carried out with nine students randomly selected from the classroom and the data obtained from these interviews and researcher teacher's observations were analyzed qualitatively. The findings as the changes in students' views were combined under 3 categories; students' views about environmental problems; students' own individualized role in environmental problems and students' views towards integration of environmental education and mathematics. This study may provide valuable contributions both to the mathematics education and science education fields in this regard.

Key words: environmental education, math, science, sustainability

1. Introduction

In contemporary world, problems concerning environmental issues become widespread and vital to solve future oriented concerns (Şimşek, 2011). Moreover, environmental education has gained much more importance and emphasis in order to develop positive attitude towards environmental issues and to make people aware of the needs, threats and significance of environmental facts (Mutisya & Barker, 2011). At that point, it is crucial that environmental education should not be restricted only to science lessons; they should be integrated in all curriculum areas by teachers while planning their lessons and teaching. Namely, not only in science courses, but also in other courses, environmental education and sustainability issues should be handled as a complementary part for the contents of the lessons. This integration may help for grounded understanding of many issues and concepts for other courses while relating these concepts to real world's environmental problems (Allfrey, 2001).

Based on the idea that environmental education needs solutions from interdisciplinary perspective, (Clark, Heimlich, Ardoin, & Braus, 2020), the present study focuses on collaborative consideration of mathematics education and environmental education. As Skovsmose (2001) highlights, mathematics has a substantial role in society and thus mathematics education and critical issues in the education may be concentrated together. From this point, although mathematics and environmental issues seem to be unrelated and distinct concepts that are separately vital in educational contexts, it is an important idea to take attention to their interrelations. In other words, beyond this relation, it is bidirectional that both mathematics and sustainable development needs each other in order to reach meaningful inferences (Hersh, 2006). Hence, combining mathematics and environmental issues may be a practical way to increase environmental awareness of students and this integration may provide real contextual problem stories to classrooms (Jianguo, 2004).

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There is a vital hidden reality that although it is not obviously seen and accepted, mathematics is the building block to reveal the facts of environmental issues. That is, without using mathematics and models, it is not easy to obtain conclusions about environmental facts because to solve these realistic mathematical problems, there is a real need for mathematics (Murphy, 2007). Similarly, as Henson and Hayward (2010) stated, ecologists and biologists need to use mathematical tools to meet their goals. Thus, to make cause-effect relations in the environment easier and more clear, interdisciplinary perspective is necessary. Besides, mathematics is a unique way which helps to make reasonable explanations for the current situations, as well as to make interpretations and suggestions for the future cases (Boland, Filar, Howlett, 2010). Hence, mathematics is essential in order to understand and make environmental facts clear because it enables to reach a common point while analyzing environmental issues (Hersh, 2006). Based on this idea, in Jianguo (2004)'s study, teachers carried out a plan to develop mathematics projects in the context of education for sustainable development and students constructed their own projects by using both mathematical and environmental issues in China. By this way, not only students enjoyed and made meaningful inferences about the reality and critical sides of these environmental issues but also lightened the teachers' perspectives about environmental issues and awareness.

In addition to these, as a way to increase environmental awareness and enhance students' attitudes toward environmental issues, mathematical textbooks are good ways to reach students. In Spiropoulou, Roussos and Voutirakis's (2005) study, how frequently environmental issues are handled in mathematics textbooks in Greece was investigated. After their investigation, they concluded that including environmental issues in mathematical textbooks seriously affects students' attitudes and awareness. Furthermore, mathematical textbooks, which seem as abstract and scaring for students, became more meaningful and students used their problem-solving skills to solve environmental grounded problems which are more related with their daily lives.

In spite of the contributions of this integration, combination of mathematics education within the base of environmental concepts has not been studied in dept. Hence, there is a lack in studies integrating the mathematics concepts and environmental education as a method for elementary students, especially in Turkey context. Making such an integration study and assessing this integration may be a remedy to increase the students' awareness and provide an opportunity to see the change in students' views. Besides, this integration study may show a way for the future studies about similar integration studies that may contribute both to environmental education and mathematics education fields. Hence, due to this gap in the area, in the present study, the activities integrating the environmental and mathematics education issues were developed and students were engaged with these activities. Then, it was aimed to reveal how participating in these activities changed the students' views on sustainability. The question being asked here is how 5th grade students' views toward sustainability change with the use of environmental awareness concepts into mathematics education.

2. Methodology

2. 1. Procedure

Based on the aim of this study, qualitative research design which gives valuable information to reveal the views of the participants about a phenomenon (Creswell, 2009) was used to explore the changes in the views of students. More precisely, case study approach which enables to obtain detailed data about a program, process or task in its real-life context was used through the study and the researcher teacher integrated the mathematics and environment education contents to the 5th grade mathematics curriculum lessons. Thus, in terms of sampling procedure, convenience sample was used so that researcher's 5th grade mathematics classroom in a private school in Çankaya district of Ankara in Turkey was integrated with the environmental awareness issues. In these classrooms there were seventeen students, as 9 girls and 8 boys, and the students and their parents were informed about the aims of the study.

In addition to the sample of the study, activity plans were other core point for the methodology of the present study. These activities were prepared by a university instructor in the field of elementary

science education and the author, as the researcher teacher in the field of elementary mathematics education. While developing the activities, students' regular mathematics curriculum and programs as well as their mathematics textbooks were taken into account and issues critical for sustainability education were integrated to the math activities. After this development process, the activities were evaluated in terms of their correctness in the subject matter, efficiency in reaching the objectives specified and the aim of this study by two experts in the field of mathematics and science education. These activities which were related to the math and environmental objectives were summarized in Table 1 and applied in the classroom for 5 weeks. Each activity was used in a week in two lesson hours as a regular part of the mathematics teaching processes of the classroom. That is, each activity lasted two class hour and as totally, ten class hours were spent for the application of these activities in classrooms.

Table 1. Activities used through the study

Name of the Activity	Related Math Objective	Objective for Related Environmental Awareness Issue
Aluminium Cans Activity	Students create research questions that require data collection. Students collect data related to research questions and display it with frequency table and bar chart.	Students recognize their own consumptions about usage of aluminium cans in a day, week, year and generalize these results to the people in the world and sources in the environment.
Plastic and Carton Bag Activity	Students collect data related to research questions and display it with frequency table and bar chart. Students solve problems related to interpretation of data shown with frequency table or bar chart.	Students recognize their own consumptions about usage of aluminium cans in a day, week, year and generalize these results to the people in the world and sources in the environment.
Water and Math Activity	Students solves and set up problems that require addition and subtraction with fractions whose denominators are equal or whose denominator is a multiple of the other's denominator.	Students recognize needed water for various foods, items and supplies; the water needed to produce those foods or items
Ecological Footprint Activity	Students express a fraction with a denominator of 10, 100, or 1000 in decimal notation. Students writes and read the decimal notation of fractions that can be expanded or simplified to a denominator of 10, 100, or 1000. Students perform addition and subtraction of numbers with decimal representations.	Students calculate their own ecological footprints, observe and discuss their classmates' footprints Students recognize the conclusions of their actions in terms of usage of natural sources.
Carbon Footprint Activity	Students writes and read the decimal notation of fractions that can be expanded or simplified to a denominator of 10, 100, or 1000. Students compare decimals based on their place value.	Students calculate their own carbon footprints, observe and discuss their classmates' footprints Students recognize the conclusions of their actions in terms of usage of natural sources.

2.2. Data Collection

Before the application of these tasks in classrooms, in the beginning of the semester, semi structured pre-interviews reflecting students' initial views about sustainability and environmental awareness issues were carried out. The participants of these interviews were nine students, 6 female and 3 boys, randomly selected from this classroom in a private elementary school. For the pre-interviews, interview questions about students' views and experiences on environmental issues and the relationship of these issues with their mathematics lessons prepared and asked to the students. All these face-to-face interviews were conducted individually with the researcher and a student in a comfortable environment that students did not hesitate to share their views. The data obtained through

these interviews were audio typed and notes were taken by the researcher. After those interviews, five distinct activities, designed and integrated through the study, were used as complementary part of the concepts taught in regular math curriculum. During this process, to triangulate the data obtained from the interviews, the researcher teacher conducted observations about the changes in students' reactions, views and awareness on the issue and took them as notes to the logbook.

Then, after applying those activities as a part of regular instruction, students were interviewed again at the end of this process. In these post-interviews, questions similar to the ones in pre interviews were asked to the same participants and their views were taken after usage of activities integrating environmental issues and mathematics concepts in classroom. In addition to those questions, direct questions to understand how these integrated activities changed their views about sustainability and environmental issues were also directed to the students. As in pre interviews, all face-to-face interviews were conducted individually in a comfortable environment and when needed, follow up questions were asked to the students in order to get more detailed information and opinions on the subject.

2.2. Analysis of Data

As the first step for analysis process, preparation of the qualitative data for analysis was conducted. For this, all data obtained through interviews were transcribed and to get meaningful influences and whole descriptions, all transcribed data and observation notes in the logbook were read and a general sense about data could be obtained (Creswell, 2009). For the confidentiality of the participants; their names were used by giving pseudonyms to each of them (like P1, P2, PE, etc...) and weren't used as explicitly in order (Frankell & Wallen, 2006).

After this process, all the data needed to understand the changes in the students' views were included to the data analysis and codes of study emerged from the data itself. As the initial step, the data reflecting students' awareness and ideas as well as the changes in their views were coded and checked by two coders. Then, similar codes were combined under sub-categories and then categories. By this way, all necessary data was coded, categorized and then lastly interpreted so as to explore the issue in detail and to have a clear understanding about students' views. The change in participants' views was explained by a cross comparison of their views in the pre and post-tests as well as their reactions in classroom observations. After this categorizing process, all data was compared to reveal the changes in the views of students, which constructed the findings of this case study, as described in the following section.

3. Findings

Data, which was obtained through data collection and analyzed through qualitative data analysis procedures, were interpreted and the changes in students' views were combined under 3 categories. That is; first category included changes in students' views about environment; second category included students' own, individualized role and the last category included students' views towards integration of environmental education and mathematics. All pre-post interview and observation data were combined under these categories; thus, comparison of these data is interpreted based on these three categories, as presented in the following section of this study.

3.1. Students' Views About Environment

Data obtained from the pre interviews and initial observations reflected that students' views about environment was limited and they have a narrow point of view about environment. Namely, when they were asked about what they understand when they hear "environment", all the students mentioned about environmental problems. Moreover, they handled the environmental problems as only environmental pollution and mostly focused on throwing away the rubbish as P1 stated:

"Environment is not throwing litter. We should warn the people".

As seen, it could be concluded that the environment, environmental problems and sustainability could not go beyond the necessity of not throwing garbage for them. Their sensitivity and awareness were limited to the garbage dumped in the environment.

Additionally, two of the students had relatively broader perspectives, but still limited, that they mentioned about air pollution and water pollution in addition to the throwing garbage on the grounds. However, it could be seen that students' views about environment and sustainability were restricted to environmental pollution and they supposed that pollution and environment is just something related with the garbage in the ground.

On the other hand, after implementation of environment activities in students' mathematics lessons, their viewpoint was broadened. It was observed through the activities that the students were surprised while recognizing the environmental issues and it was seen in data of post interviews, too. The students could form sentences also with seas, trees or other natural sources; thus, they handled this environment issue from a broader concept. To illustrate from the post interview data about what they understand for the environment term:

P3: "Something we eat, we drink, we use, everything is environment."

P4: "When anybody says environment, people come to my mind. We use environment, it is in everywhere. In our house, in our school, in our roads, even if in our holidays."

As can be seen from students' sentences, by involving in the mathematics lessons which are integrated with the environmental education issues, the students' perception and views about environment changed in away that they could look from the wider perspective about the environment and environmental issues. Here is some of the examples from the students' sentences that revealed the change in their views:

P7: "At past, I thought that environment is like environment pollution which is only related with garbage. But now, I don't think so. Every product that we waste unnecessarily can be related to the environment."

Similarly,

P2: "Even the water used in the production of some foods is actually something related to the environment and our resources."

To sum up, data obtained through the study reflected that after participating in the events, when students think of the environment, they do not only think of throwing garbage in the environment or routine environmental pollution. It was observed and deduced from the interviews that the words and perspectives used by the students while expressing the environment and environmental pollution changed, and in this sense, they could have richer and more accurate information and point of view about environment.

3.2. Students' Own Role in Environment

In the second category of the findings, students' responses in terms of their own role in environmental issues are handled. In the pre interviews, it was seen that all of the students interviewed thought that they do not harm or use the environmental sources needlessly. They saw that their role is to warn people not to throw the rubbish or garbage away. None of the students blamed or criticized their own actions and all of the students thought that the people who may harm to the environment is someone different from themselves. For example:

P2: "I don't think that my objects or belongings harm the environment. I use all of my objects."

Similarly,

P7: "As an individual, I usually warn the people. I do not disturb the environment. I do not throw the rubbish away and I warn them not to do."

As seen, before the activities, their views were limited to throwing the rubbish away and thus, they thought not harming the environmental sources in any way. Even, two of the students mentioned about other countries as the only sources of the environmental problems. To illustrate,

P8: "The ones harm to the environment is rich and huge communities, countries and especially rich people. They use needless."

However, after activities, they broadened their viewpoint that people may harm to the environment even if they do not throw litter. Even, the observation notes indicated that the students started to warn their friends for their own actions or shared the differences in their life in this regard. In line with this, they shared their views about what they learnt by means of the activities they used in their mathematics lessons or how their views were changed in terms of their own roles in the environment. Examples from the students' statements are provided below:

P7: "I learnt in my mathematics lesson that I use 5 worlds although I have only one. Now, I'm paying attention while using everything because I actually harm to the world in some of my actions. I learnt that our sources are limited. I try to use and consume everything cautiously."

P4: "Now, I changed. I do not waste bugs, cans, papers or my clothes. Even clothes need water, where does water come? From the environment. So, I try to use them carefully."

P2: "I may harm to the environment. Everybody may harm to the environment but most of the people even do not aware of this."

As can be seen from the sentences of the students, the calculations they made in the mathematics lessons and the results of their math activities raised their awareness that their own actions could harm the environment without realizing it. Thus, they could notice and interpret their own role in environmental issues.

3.3. Students' views towards integration of environmental education and mathematics

In the third category, students' responses were handled in terms of their views on integration of environmental education and mathematics education in classroom tasks. At the beginning of the study, students were asked about integration of the lessons, and they were wanted to share their ideas about which lessons can be integrated with each other. According to their views, associating the lessons with each other can be a good and useful practice, and all of these students gave prefixes for this association other than mathematics and science lessons. The students, who gave examples about which courses can be associated, mentioned that Turkish and social studies or social studies and science courses can be associated. Nobody said that, environmental issues or environmental problems can be topic of the math lessons, they couldn't give examples about integration of mathematics and science or environment education. Even, after the researcher propose this and ask what if or how they learn those issues in mathematics lessons, most of the students thought that it is not a good idea to integrate those two. To illustrate:

P1: "It does not sound good to mention environmental issues in mathematics lesson."

P6: "It seems bizarre to integrate math and environmental education. It is science lesson."

While all the students found this integration meaningless, only one commented that it might be possible and explained how this integration can be, although her idea is very limited. That is,

P2: "We solve problems in math. We can learn with them."

Researcher: "How can you learn from them?"

P2: "For example: There are 12 trees. Ali cut down 1/3 of them. If they do this needlessly, we can learn something from mathematics lesson."

On the other hand, at the end of the semester, students were exhausted to share their learnings from their mathematics lessons and they were happy with this integration. They were all satisfied from including those environment activities in their mathematics lessons. Even, one of them states this as:

P4: *"Mathematics was boring for me, but I calculated how many my aluminum cans I use in a year. It was a lot but as much as an American use."*

In addition to positive feelings about activities, they were exhausted toward future similar activities in their mathematics lessons. Not only all of the students were happy, but also, they increased their awareness with the help of this integration. One of the students mentioned about this as stated below:

P7: *"I changed many things in my real life."*

The researcher: *"What kind of changes do you mean?"*

P7: *"I mention everything. For example, I wanted my mother to give my clothes to other people. If I throw it to rubbish, other people have to buy new clothes. New clothes mean new water usage. It is needless. I learnt them in mathematics lesson."*

The researcher: *"Do you remember that you laughed when I asked you if math and science could be associated? What do you think about this right now?"*

P7: *"Yes (laughing again). I must have thought unconsciously and simply. Of course, it's relatable and even, this association is very useful. It made me realize many things by which I had never thought of before. It also made the lesson fun. I even warn my parents, I explained them what we have learned here."*

Data both in observations and interviews indicated that, by means of the integration of the activities, the students could be aware of the power and the importance of this integration and the students realized their individualized role, effect and own responsibility for the environment at the end of the study. Besides, they were knowledgeable about mathematics' helpful side for the environmental education and they were aware that both mathematics and environmental education need each other to get meaningful inferences. Furthermore, as it is clearly seen, the changes in their views were obvious in each of the categories: students had more things to say when compared to their initial interviews for all three categories and they were more aware of the issues related to environmental education.

4. Discussion and Conclusion

The aim of this study is to explore the changes in the views of 5th grade students toward sustainability with the integration of environmental education into mathematics education lessons. In accordance with findings of the present study, it could be easily seen at the beginning of the study that, there was a tendency among students that their views about environment were restricted. When they talk about environment, they could only mention about environmental pollution like throwing the garbage away and their own individual role on environmental problems were overlooked. That is, the students never thought that they might be involved in this incident, and they never questioned their behaviors in life in terms of environmental problems. Additionally, the students were not aware of the relationship of mathematics and environmental issues and their facilitator role on each other.

As the findings reflect, students were willing to study, learn and search about environmental issues and also keen to take precautions about them. Hence, it was meaningful and effective to integrate these issues in their mathematics lessons. By this way, the students not only could see that mathematics is required in everywhere but also became more aware about environmental issues. By using their mathematical knowledge and skills, they recognized the effects and their own roles in the consumption of natural sources cautiously. The students' views reflected that they had a much wider perspective on issues about natural resources, their sensitivity to environmental events and meaning assigned to the environment itself were changed.

In line with these positive changes and the role of integration of mathematics and environmental education on students, this study may provide a guide for teachers and curriculum developers. The conclusions of this study also coincide with the Jianguo (2004)'s suggestions that middle school mathematics lessons may be used to teach environmental education for students, as he also proposes some examples in his study. In addition to this, findings of this study can also be interpreted that integration of environmental issues in mathematics lessons may enable students to be more motivated to mathematics lesson. The students in the study calculating their own consumptions and could see

their effects on the environment. Learning from their own real life might helped them to see that mathematics is not an abstract concept in fact, it is meaningful and needed in their daily life and actions. Namely, it may show that mathematics is in the real life; as in stated By Van de Walle, Karp, & Bay-Williams (2013), it helps and gives meaning for real life.

In addition to those positive effects to mathematics, it has positive contributions for the objectives of environment education (Hersh, 2006). Saying to students that we, as people, harm the environment unwittingly, is not an effective real-life sentence as long as people do not experience it. Students hear those types of sentences almost every day and in every science or other related lessons. However, showing them this fact by calculating and revealing their own effect, and teaching those by doing in their mathematics lesson show the case in a different perspective (Boland, et al., 2010). Hence, this may increase their consciousness and provide a way to feel their own responsibility. Besides, it is not so difficult for a teacher to involve those in their own lesson plans. On the contrary, it may make easier to plan their own mathematics lessons by involving one or more environmental issues or calculations in their lessons. Moreover, when this involvement takes the students attention, as observed in the findings of the present study, they become more motivated to solve problems, complete activities or tasks, which may decrease the classroom management problems. Hence, teachers may benefit from the facilitator effect of this involvement.

To sum up, since development of positive environmental attitude of young people in Turkey is important (Tuncer, Ertepinar, Tekkaya, & Sungur, 2005), it may be vital to make the student realize that environmental issues and mathematics are not separate and distinct concepts and they can make many inferences by using these together. On the contrary, they are all related and needs each other and it is crucial to make the students aware of this reality (Hersh, 2006; Jianguo, 2004; Murphy, 2007). Hence this study may provide valuable contributions both to the mathematics education and science education fields in this regard. The findings are limited to the sample of this study; thus, for further research on this issue, studies that uses these or similar integration tasks with other samples may be conducted or tasks for different grade levels may be developed. Moreover, dissemination studies with various contexts from different countries and quantitative studies that help to generalize the changes in students' attitudes with more participants might be conducted.

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Author

Duygu ÖZDEMİR, Assist. Prof. Dr., Istanbul Aydın University, İstanbul (Turkey).
duyguozdemir5@aydin.edu.tr.