An Interview Protocol for Assessing Students' Understanding of Dynamically Complex Environmental Problems

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ABSTRACT

The present study includes development of a qualitative tool to assess student interviews on some specific dynamic environmental issues and preliminary results from eight student interviews selected from a public school in Istanbul. This protocol has been designed for an educational research with seventh graders (12-13 year-olds) to teach "Human and Environment" science unit with systems approach. The research is a quasi-experimental study that enables the researchers to test improvements in general systems thinking skills, competence in dynamic environmental problem solving, and success in standard science achievement tests. Mixed method of data collection, including both quantitative and qualitative aspects, has been used during this research to enrich data collection. Systems literature is deficientt in assessment tools for systems thinking skills in various contexts and for various age groups. This protocol will be a contribution to systems literature in terms of adopted environmental context and the target age group. Moreover, the interview questions do not include any system-specific terminology that disables researchers to use it with control groups or in research without systems intervention.

Keywords: Systems based education, systems thinking skills, dynamic environmental problems, interview protocol.

I. INTRODUCTION

We are facing an accumulation of environmental problems that have not been solved for a long time. Educating people about the background, underlying reasons, and scientific content of long-lasting environmental problems would be a valuable attempt to influence next generations.

Environmental education is related to *"changing the way people think about their environment*" (Wylie *et al.* 1998; p.117). Wylie *et al.* (1998) criticize that although there are sufficient number of researches on children's ecological knowledge, there is less emphasis on how children think about and understand the "system" operating around them in the literature. The fundamental problem about formal environmental education is limited school curricula in terms of ecological content (Grotzer and Basca, 2003). So, less time is devoted to teaching ecological subjects, that is supposed to change the way students think about the environment.

Moreover, in most of the cases, teachers think that ecological subjects are easy to understand for students; however Grotzer and Basca (2003) mention several studies on misconceptions about ecological content that students at different grade levels have.

Within the complexity of ecosystems, one should be aware of shifts from equilibrium to non-equilibrium states, focus on multiple routes of causality over unidirectional causality, and reveal the messy relationships of biotic and abiotic components within the whole (Hogan, 2000). Parallel with the demands of understanding ecosystems, Sterman (1994) describes systems thinking as *"the ability to see the world as a whole"* (p.291). Riess and Mischo (2010) also express systems thinking as "*the ability to recognize, describe and model complex aspects of reality as systems*" (p.707). Besides, they also focus on awareness of time dimension to model and to make projections for future behaviors of a system. Riess and Mischo (2010) criticize that without considering socio-cultural and economic aspects, stressing solely the ecological aspect of sustainable development is deficient.

To fulfill the main goal of environmental education; that is, changing the way people think about their environment, some of the requirements are comprehensive assessment tools that should include items related to systems thinking skills. These tools will enlighten children's current conceptions about ecosystems and the effects of any interventions on their conceptions about environmental problems. However, the systems literature lacks sufficient systems based educational materials (Mandinach and Cline, 1993; Zaraza and Fisher, 1999, Nuhoğlu, 2008) and assessment tools (Sweeney and Sterman, 2007; Nuhoğlu, 2008). Taking these limitations into account, the present study aims to create an interview protocol to assess students' elementary systems thinking skills and their understanding of dynamically complex environmental problems. The protocol is used in a pilot study of an educational research and eight interviews with seventh graders are coded and evaluated accordingly.

II. METHODOLODY of the OVERALL RESEARCH

II. I. Research Design

The design of the overall research is *quasi-experimental,* in which there are variables that will be under control in the field (classroom) and in the absence of random assignment. Gribbons and Herman (1997) support quasi-experimental research designs in studies where effects of certain educational programs are evaluated and when it is not plausible to deliver random assignments of subjects.

In the research, the independent variable whose effects will be tested on the subjects is the intervention program that is based on "systems approach". The dependent variables, which will be evaluated via pre- and post-tests, are general systems thinking skills, competence in dynamic problem solving, and success in standard science achievement tests. The instruments are prepared by the researchers. In addition to the written instruments, semi-structured interviews are conducted with randomly selected subjects from each group. Table 1 summarizes the design of this study and illustrates the sequence of activities followed throughout the research. It is important to note that both the experimental and control groups take exactly the same tests at the same stages during the research.

Table 1. Design of the overall research

Experimental Group	**Control Group**
Pre-tests (1 hour) *-Demographic Information Sheet* *-Systems Thinking Skill Test (A)*	Pre-tests (1hour) *-Demographic Information Sheet* *-Systems Thinking Skill Test (A)*
Introduction to system dynamics (3 hours)	Meeting with students (1 hour)
System Based Intervention (16 hours)	Standard Instruction (16 hours)
Post-tests (2 hours) *-Systems Thinking Skill Test (B)* *-Science Achievement Test* *-Dynamic Environmental Scenarios*	Post-tests (2 hours) *-Systems Thinking Skill Test (B)* *-Science Achievement Test* *-Dynamic Environmental Scenarios*
Application of Dynamic Environmental Scenarios Protocol (15-20 minutes for each interviewee)	Application of Dynamic Environmental Scenarios Protocol (15-20 minutes for each interviewee)

II. II. System Based Intervention Program

The "Human and the Environment" chapter of the Science and Technology course for seventh graders is re-designed based on systems approach. The content of the chapter is not changed, but activities on cause-effect thinking, feedback thinking, stock-flow thinking and dynamic modeling with STELLA are included.

The Science and Technology Curriculum recommends to allocate 16 class hours for the "Human and the Environment" chapter. The systems based intervention is designed for 16 lesson hours as well, except the application of pre and post-tests. Moreover, an extra three–hour introduction is allocated to teach the basics of system dynamics. This introduction covers the topics on

- systems in general
- causal loop diagrams,
- feedback loops,
- stock-flow diagrams,
- constructing simple models with STELLA

The environmental concepts within the chapter such as habitats, populations, species, ecosystems, etc. and their order of introduction are common for both instructions. Moreover, some activities are also common with some minor additions of system elements. In short, the standard program for the control group is designed according to the unit plan suggested by Turkish National Education Ministry (MEB), while some modifications and extensions to integrate system elements into the program are made to design system based intervention program for the experimental group.

II. III. Quantitative Instruments

There are three quantitative instruments that are conducted within the overall research. "Systems Thinking Skill Test" (STS test) includes fill in the blank, true-false, short answer and essay questions. The questions are designed in a way that a natural system thinker can answer the questions without having any knowledge about the field specific terms like stocks, flows, feedback loops, etc. STS test includes two parts: The first part is on required skills:

- ✓ Interpreting graphs, creating graphs from data,
- ✓ Telling a story from a graph, creating a graph of behavior over time from a story,
- ✓ Identifying units of measure,
- ✓ Basic understanding of probability, logic, and algebra

as suggested by Sterman and Sweeney (2000). The second part includes questions on:

- ✓ feedback structures,
- ✓ stock-flow thinking,
- ✓ delay,
- ✓ leverage,
- ✓ predicting behavior of a system.

To inhibit recall of items in the tests by the subjects, creating "equivalence forms" are suggested in pre- and post-test research designs (Gay and Airasian, 2003). Equivalence tests have the same number of items, the same difficulty level, the same directions for administration, the same scoring, and interpretation. Sterman (2010) also strongly advises to use parallel tests after reviewing and comparing the latest studies done with students at varying grade levels and their systems thinking skill performance on various system-related tasks.

"Science Achievement Test" is a common exam that is applied as a post-test to all subjects. The questions are selected and modified from various science text books and they are redesigned for this study. The test has been prepared by taking into account the objectives listed in the suggested chapter plan by Science and Technology Curriculum.

"Dynamic Environmental Scenarios" is applied as post-test. This test includes five different scenarios; two of the scenarios are about unfamiliar environmental problems (which had not been taught within the instructions) during the intervention. These questions are on the construction of a new suspension bridge and its highways; and on collection and deposition of solid wastes. The questions in familiar context are on population dynamics and bioaccumulation. Identifying variables of a system, feedback loops, stock-flow thinking, behavior over time, leverage, and delay constitute the system content of this instrument.

II. IV. The Interview Protocol

This paper focuses on the qualitative interview design, coding of students' responses, reliability analysis of the codebook, and evaluation of the students' responses. This protocol will enable to enrich the data collected, to compare data collected in different techniques, and to present results in various different formats. "Explanatory Mixed Method Design" has been chosen for this study. This design implies an emphasis on quantitative data collection. According to explanatory mixed method design, quantitative data is collected and analyzed at

the first hand. Then, based on the results of the quantitative part, a qualitative phase is conducted. Qualitative data collected will help to understand and explain the quantitative data in depth (Gay, Mills, and Airasian, 2006).

Based on the characteristics of the "Explanatory Mixed Method Design", "Systems Thinking Skill Test" (STS) both as pre and post-test in alternate forms, "Dynamic Environmental Scenarios" (DES), and "Science Achievement Test" have been applied firstly as quantitative instruments. These tests include some open-ended questions where the subjects are expected to reflect their way of thinking about an environmental problem or a subject that has dynamic characteristics. Although the subjects would like to express their thoughts in the courses during the pilot study, the problem is that their written responses were extremely short; with a few words in most of the cases. Hence, interviews with a limited number of subjects would be helpful to get more insight about their thoughts on dynamic issues.

To get a deeper understanding of subjects' responses on the various ecological issues and some other dynamic issues addressed in the written tests, the same questions were asked with some probing in the semi-structured interviews. In semi-structure interviews, there are a set of questions to be asked, and an interview guide with exemplary probing. The interviewer is flexible and is able to make changes in order and details about the questions. But, the questions should be similar to make comparisons. According to Bernard and Ryan (2010), semi-structured interviews are appropriate for the respondents who cannot be interviewed in a formal manner. Hence, conducting semi-structured interviews is a good choice for a sample consisting of seventh grade students.

The interviews were conducted three weeks after the pilot study was completed. Eight subjects were selected in accordance with their varying performance throughout the intervention. The range for the duration of interviews was 15 to 27 minutes.

II. V. Qualitative Analysis of the Student Interviews

For the qualitative analysis of the interviews, the first step was transcription. To avoid *data distance*, which is related to *"the amount of information lost in the process of recording it"* (Bernard and Ryan, 2010; p.46), waiting times, some instances like laughter, wonder, "a-ha moments" were included in the transcription text.

The second step of the qualitative analysis is the design of a codebook including levels for each question (The codebook has been translated into English and uploaded as a supporting material). The specified codes are all related to systems thinking skills and the main idea is how these skills are embodied in various dynamic situations. Some typical examples for each level were placed in the codebook. These typical examples are among the responses of the subjects in the pilot study. Only two levels could not be exemplified. These levels were mentioned with endnotes and an expected response was written for each level in the codebook.

To study the inter-rater reliability of the codebook, two researchers assessed an interview with respect to the codes and levels mentioned in the codebook independently. Only one slight disagreement was detected in the bluefish question and it was resolved with a correction on the way that specific question is posed.

According to the codebook, the assigned levels for each question and each student are summarized on Table 2.

Table 2. Results of the qualitative analysis

Subject Name[3]	Causal Loop Thinking (0-2)	Delay (0-2) [# of registered vs. graduated students]	Stock-flow Thinking (0-1) [# of passengers in a bus]	Stock-flow Thinking Behavior of a System Feedback Thinking (0-2) [Bluefish population]	Stock-flow Thinking Behavior of a System Feedback Thinking (0-2) [Suggestions for bluefish population]	Feedback Thinking (0-2) [3rd bridge and traffic]	Feedback Thinking (0-2) [Suggestions for traffic]
Can	2	2	1	2	1	0	1
Emir	0	1	1	1	1	0	0
Ruhsar	2	1	1	1	0	0	0
Ali	1	2	1	0	1	2	0
Işık	2	2	1	2	0	0	0
Yeliz	1	1	1	1	0	1	1
Özgür	2	2	1	0	0	1	1
Nil	1	1	0	0	0	0	1

The next step in qualitative analysis should be to look for internal consistency within scores of the same systems thinking skills (STS) and scores of individuals of different skills. When the same STS are taken into account, it is hard to conclude that every question addressed to a certain skill has a similar pattern for each individual. In other words, an individual's score on questions about stock-flow thinking are not always parallel. The patterns become more complex when questions related to suggestions are taken into account. When individual scores are taken into account, this assessment seems to be reliable. Because, the ones reached higher levels tend to possess a number of STS and vice versa.

The last step in qualitative analysis would be to compare responses in quantitative and qualitative instruments. When scores of the same individuals from the qualitative and quantitative instruments are compared, they seem mostly parallel. In spite of the parallel findings, conducting only quantitave data collection would be insufficient when the cases listed below are taken into account:

- ✓ Subjects tend to give shorter and more general answers in the written tests especially to the bluefish population question.
- ✓ Subjects tend to disregard some hints and details in the written tests. However, the interviewer is able to warn in case of any misunderstandings. (3rd bridge and bluefish population questions)

[3] Subject names are disguised.

- ✓ Subjects tend to give papers with more empty answers, while in interviews they try harder to respond. (Only one subject said "I don't know" to one question during the interview, while the papers were full of empty answers.)
- ✓ Some interviews took nearly half an hour, because the subjects also asked some questions to clarify their minds about the questions. In such conversations, the interviewers were able to get more insight about their views and get more feedback to identify the levels specified in the codebook.

Conclusion:

This paper is on designing a qualitative instrument for assessing STS by addressing dynamic environmental problems. This instrument has been used in the pilot study of an educational research. It is also being used in the experimental part of the study to compare responses of subjects from the experimental and control groups after being taught a science chapter with and without the presence of systems approach, respectively.

The pilot study was conducted with 56 seventh grade students from two different classes. Systems based intervention program was applied to all the subjects. Hence, there was no control group in the pilot study phase of the research. The researcher prefered to teach with systems approach to the two classes to get some teaching experience and to get feedback after two sets of intervention. The exciting part of the question will be answered after the experimental study; whether the system based intervention would make sense in terms of the STS, competence in dynamic environmental problems, and science achievement test, compared to the standard teaching.
Although there has not been a comparison between the performance of the control and experimental group, the preliminary qualitative results from the pilot study showed that;

- ✓ Half of the subjects are able to complete causal loops,
- ✓ They are all aware of stocks and delays.
- ✓ Subjects have difficulty in proposing sound suggestions for complex environmental problems.
- ✓ Their suggestions are not always parallel with their deductions.

The present study is significant in the sense that a new alternative qualitative instrument has been developed. This is the first Turkish qualitative instrument developed specifically for systems based education practices for children. Development of this instrument is an attempt to fulfill the deficiency of systems based assessment tools (Sweeney and Sterman, 2007; Nuhoğlu, 2008).

ACKNOWLEDGEMENT

This study was supported by Bogazici University Scientific Research Projects Commission, enabling the provision of the materials, instruments and services required for this study.

Project no: D5729. Project date: 2010-2012**.**

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