The effect of the system dynamics approach on understanding causal relationship skills in science education

Hasret Nuhoğlu*

*Maltepe University, Istanbul, Turkey

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Abstract

The aim of this research is to investigate the effect of system dynamics approach, in understanding of cause-effect relationship. The experimental design with pre-post test with control group is applied in this research. In order to assess the sub problems of the study, a valid and reliable “Cause-Effect Relationship Scale” had been developed by the researcher. Collected data were analyzed with the help of descriptive statistics, paired and independent t-tests. The scale for “understanding cause and effect relationship” has two sections. In the first section (causality 1), the interest and attitude of the students towards cause and effect relationships are evaluated. In the second section (causality 2) the cause and effect relationship commenting skills of the students in some sample cases are evaluated. In the first section the initial mean values of experimental and control groups are different whereas, their mean scores are equal in the end of the empirical study. As per second section, in the end of the empirical study, it is obvious that cause and effect relationship skills of the students have been increased after system dynamics application. Statistically there is not a significant difference in cause and effect relationship oriented of interest and attitude (causality 1) of the students in the end of empirical study (t = 0.00; p>.05). In the classes where system dynamics approach is performed, it is obvious that ideas of the students about cause and effect relationship did not change. The results gained from causality 2 scale shows that there is an increase in previous and post empirical study in both groups. Cause and effect relationship is understood better by the students in experimental group, according to mean scores. It can be said that the system dynamic provides benefit of understanding and commenting of cause and effect relationship.

Keyword: System dynamics approach; cause-effect relationship scale.

1. Introduction

System dynamics is a well formulated teaching and learning methodology for analyzing a system that includes cause-effect relationships and their underlying mathematics and logic, time delays, and feedback loops. Having inspired by successful policy changes in lots of fields such as engineering, management, economy, physics, chemistry and biology, the system dynamics researchers targeted to apply the system dynamics approach in the educational fields too. First educational applications showed that important improvements can be obtained in this field as well. The students in the schools, where system dynamics approach is used, run voluntary projects in
relation with their school courses even after the school time. Also the students became so enthusiastic with the subjects that they made their parents to take part in the projects. There is a remarkable increase in the interest and understanding level of the students to the courses (Alessi, 2005; Fisher, 1994; Forrester, 1992; 1996; Lyneis, 2000; Zaraza ve Fisher, 1997). Therefore, a few curriculum projects (Stacin, Ce-Status, Ce-Sustain, Science Ware) based on the system dynamics have been developed. By using these projects, a lot of new ideas and useful models are provided for the practicing teachers to apply system dynamics in the classroom (Forrester, 1996; Lyneis, 2000). Using system dynamics approach the modelers produce simulation tools called as micro worlds. The students use these tools to make certain experiments. These tools are actually replacements for the real world. The experiments in the micro worlds can be repeated easily using varying parameters and alternative scenarios. This allows the student to see how the dynamics of the system works, by experiencing it in the virtual world. Usually, there is no other way of observing the results of the experiments outside of the micro worlds. In this research, Stella simulation program was used because, Stella is the mostly preferred tool for the K-8 students (Brown, 1992; Forrester, 1996). System dynamics approach makes it easy for students to focus on the causes of the events. Moreover, students understand that there are usually more than one cause and effect relationships under the complex systems. In addition, students see that the result of the combined interactions of all the cause and effects relationship cannot be analyzed by superficial studies.

The aim of this research is to 1) apply system dynamics approach in 7th grade middle school students in science and technology course, 2) improve the students’ attitude and success toward understanding the causal relationship, 3) investigate the effect of system dynamics approach, in understanding of cause-effect relationship.

2. Rational

Learning is a dynamic process. Learning concepts on its own is not sufficient to achieve a meaningful learning in cognitive level. Learning concepts in the context of their causal relationships improves the level of learning process. When students learn science concepts in the context of their causal relationships, then they perceive the topic as a whole and accomplish meaningful constructivist learning. System dynamics provides to be an effective learning and teaching tool for students and teachers. Students model concepts and cause-effect relationships among concepts with a dynamic concept map owing to system dynamics approach. Therefore, system dynamics approach determining perceived causal relationship skills and success is so useful in science education.

3. Methods

The experimental design with pre-post test with control group is applied in this research. Independent variable is “system dynamics approach”. Experimental group was taught with system dynamics approach. Control group was taught with standard syllabus. The students in experimental and control groups were selected randomly. The study was done in 2007-2008 semester with a total of 81, 7th grade students in middle schools in Istanbul / Turkey. In order to assess the sub problems of the study, a valid and reliable “Cause-Effect Relationship Scale” had been developed by the researcher in order to determine how students evaluate the relationship between cause and effect on sample events and to learn the attitudes of the students towards cause and effect relationship is used. Collected data are analyzed with the help of descriptive statistics, paired and independent t-tests.

3.1. Learning topics with system dynamics approach

The only difference between the control and experimental groups lies in the supplementary material. Supplementary material for the control group was the exercise questions written in the workbook about the topics of spring mass systems, work, and energy, energy styles and energy conservation. This supplementary material was replaced in the experimental group with modeling activities of system dynamics. The spring mass model and its simulation results in graphical format developed by students in the experimental group is shown in Figure 1 and Figure 2.
4. Results

4.1. Statistical values of mean and standard deviation

The result of pre and post test scores describing the cause and effect relationship skills of the students in experimental and control groups are shown in Table 1.

<table>
<thead>
<tr>
<th>Scale/Group</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causality 1</td>
<td>E1 38.6</td>
<td>C1 35.2</td>
</tr>
<tr>
<td></td>
<td>E2 40.8</td>
<td>C2 40.8</td>
</tr>
<tr>
<td></td>
<td>E1 7.7</td>
<td>C1 14.2</td>
</tr>
<tr>
<td></td>
<td>E2 7.5</td>
<td>C2 7.4</td>
</tr>
</tbody>
</table>

E1: experimental group pre-test; E2: experimental group post-test; C1: control group pre-test; C2: control group post-test

The scale for “understanding cause and effect relationship” has two sections. In the first section (causality 1), the interest and attitude of the students towards cause and effect relationships are evaluated. In the second section (causality 2) the cause and effect relationship commenting skills of the students in some sample cases are evaluated. In the first section the initial mean values of experimental and control groups are different whereas, their mean scores are equal in the end of the empirical study. As per second section, in the end of the empirical study, it is obvious that cause and effect relationship skills of the students have been increased after system dynamics application.
4.2. The effects of the system dynamics approach on the skills of the students to understand cause-effect relationships

The results of pre and post test scores in experimental and control groups are shown on Table 2.

Table 2. Statistical Values of causality 1 and causality 2

<table>
<thead>
<tr>
<th>Tests</th>
<th>Groups</th>
<th>P</th>
<th>t</th>
<th>df</th>
<th>sd(1)</th>
<th>sd(2)</th>
<th>is difference significant?</th>
<th>SD useful or not?</th>
<th>Experiment biased</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAUSALITY 1</td>
<td>C1 C2</td>
<td>0.02</td>
<td>-2.14</td>
<td>37.00</td>
<td>11.22</td>
<td></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>C1 E1</td>
<td>0.88</td>
<td>-1.37</td>
<td>61.70</td>
<td>14.16</td>
<td>7.69</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E1 E2</td>
<td>0.00</td>
<td>-8.85</td>
<td>38.00</td>
<td>1.69</td>
<td></td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C2 E2</td>
<td>0.49</td>
<td>0.00</td>
<td>74.96</td>
<td>7.42</td>
<td>7.45</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E1 E2</td>
<td>0.00</td>
<td>-4.64</td>
<td>37.00</td>
<td>1.30</td>
<td></td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C1 C2</td>
<td>0.00</td>
<td>-2.41</td>
<td>77.91</td>
<td>0.72</td>
<td>0.85</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C1 E1</td>
<td>0.00</td>
<td>-5.47</td>
<td>64.72</td>
<td>1.12</td>
<td>1.76</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

P: significance level, df: degrees of freedom, sd: standard deviation

The students’ answers given to the scale have been evaluated (Table 2). Statistically there is not a significant difference in cause and effect relationship oriented of interest and attitude (causality 1) of the students in the end of empirical study (t = 0.00; p>.05). In the classes where system dynamics approach is performed, it is obvious that ideas of the students about cause and effect relationship did not change. The results gained from causality 2 scale shows that there is an increase in previous and post empirical study in both groups. Cause and effect relationship is understood better by the students in experimental group, according to mean scores. It can be said that the system dynamic provides benefit of understanding and commenting of cause and effect relationship.

5. Conclusions and Implications

In the boundaries of this research, system dynamics approach had no effect in the perceived understanding cause and effect relationships (causality 1 scale). Since the study was done in a setting of 4 weeks, these results seem as expected. According to the researcher’s observations the interests and attitudes of the students towards the system dynamics approach increased steadily during the study.

Second part of understanding cause effect relationship scale consists of open-ended questions. These questions help us to assess whether the students have the ability to determine the relationships between causes and effects correctly. The answers of the questions were evaluated as true or false. After the study both control and experimental groups had an increase in comparison to their pre study levels. The increase in the mean of the experimental group was higher than control group. Therefore, it is reasonable to conclude that system dynamics approach has a positive impact on the ability of understanding causality relationships for students although the perceived attitude towards causality did not increase in the experimental group. The steadiness of attitude may be due to external factors that are not handled in the research.

System dynamics approach consists of two parts: building the model and testing it. Both parts employ mathematical equations. The relationships between the concepts are established through the mathematical relations. New curriculum in Turkey does not contain as much mathematical relations as the former one. But a student that does not know the mathematical relation between the concepts can not build the model of the system.
References


