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Improving a Sample Lesson Plan for Secondary Science Courses within the STEM Education*

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Abstract

The main goal of this study is to present a sample lesson plan on acids and bases based on Science, Technology, Engineering and Mathematic (STEM) education for Turkish Science Education System. Determining the impact of instructional materials on learning outcomes of children as a pilot study before the main implementation is also another goal. Single group pre-test/post-test design was used in the study. 12 different 8th grade students were chosen for the population of the study. The instructional materials within the STEM education were organized in accordance with 5E learning cycle model in order to teach the subject to children. Primarily, in order to determine students’ knowledge on the subject, a survey of 10 open-ended questions were presented to the students. After determining their learning outcomes with teaching interventions, the same questions were restructured. Wilcoxon Signed Ranks Test for Paired Samples, non-parametric test and Cohen’s Kappa test were used to analyze the data with SPSS 20.00 program at .05 significant levels. It was determined that achievement levels of the students on post-test were higher than the pre-test. Herewith, sample lesson plan was found to be quite effective on students’ levels of gaining the learning outcomes.

1. Introduction

Science, Technology, Engineering, and Mathematics (STEM) literacy is an important element in science related programs of 21st century. It is STEM education that has probably become the largest reform movement in PK-12 education in the last decade (Daugherty, 2013). The decisions related to individuals and societies in the 21st Century demand scientific and technological understanding more and more. What this STEM Education specifically does is...
to connect these four disciplines and give students opportunities for richer learning experiences (Figliano, 2007). STEM education has been frequently called a meta-discipline, the “creation of a discipline based on the integration of other disciplinary knowledge into a new ‘whole’. This interdisciplinary bridging among discrete disciplines is now treated as an entity, known as STEM (Morrison, 2006, p.4).” Informed decision-making requires a certain level of scientific knowledge on health, environment or technology. Hence another goal for STEM education presents itself; it is to increase STEM literacy. It can be defined as the knowledge and understanding of scientific and mathematical concepts and processes that are needed for individual decision making, participating in civic and cultural affairs, and for economic productivity for all students (NRC, 2011). STEM literacy refers to (1) obtain scientific, technological, engineering and mathematical knowledge and using it to identify issues, get new knowledge, and use it for issues about STEM, (2) comprehend the characteristics of STEM disciplines as forms of human efforts including inquiry, design, and analysis processes, (3) understand how STEM disciplines give shape to our material, intellectual and cultural world, and (4) engage in issues about STEM by using ideas related to science, technology, engineering, and mathematics as thoughtful, sentimental and contributed citizens (Bybee, 2010).

A life without technology and engineering is unimaginable. The engineering component of STEM education doesn’t just stand on the solutions but emphasizes process and design of solutions. In this way, students can discover mathematics and science in a more personal way and adopt critical thinking skills that can be used throughout their academic lives and works. Students can use engineering to explore, discover and to solve problems. One part of STEM Education can really help understanding the others. That is technology. It helps students apply what they learn, use computers and practice with professional applications such as CAD, CAM, simulations and animation softwares. Such applications of technology give students chances to explore STEM subjects in a more detailed way and in practical terms (Lantz, 2009).

Murphy and Mancini-Samuelson (2012) stated that a great deal of attention has been focused on STEM education for high school in recent years. In addition, it has begun to include middle school students. On the other hand, we believe that this emphasis must begin at the elementary level in order to get the maximum impact on students and STEM education. Science programs organized in compliance with STEM education play an important role in introducing and encouraging students in STEM fields. Still, Brown (2012) stated that it is needed to have more research on descriptive classroom applications to practice teachers and compact qualitative/quantitative studies.

It is indicated that STEM education is needed to keep up with today’s developments. For that purpose, it is essential to investigate the scope, theory, and practices of STEM education in all educational levels and reorganize the instructional programs in compliance with the approach (Turkish Ministry of National Education, 2009). However, there is not any example of lesson plans in secondary school science teaching program based on the approach. For this reason, a sample lesson plan was developed for the topic of acids and bases. That will be an example for our science teaching program in STEM education.

Thus, the main purpose of the study is to develop a sample lesson plan on acids and bases according to STEM education for our education system. It is also investigated the effectiveness of the sample lesson plan on 8th grade students’ achievement levels in a science course. In this study research questions are as follows:

1. What are the achievement levels of students in terms of gaining accomplishments?
2. Is there any difference between the pre-test and post-test scores?

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1This study is adapted from the first author’s ongoing master dissertation titled “A Study for Preparing an Instructional Design Based on Science, Technology, Engineering and Math (STEM) Approach on the Topic of Acids and Bases at Secondary School Science Course” submitted to Uludağ University under the supervision of Assist. Prof. Dr. Zehra Özdílek
2. Method

One-group pretest-posttest design was used in this study. It was determined to measure the effect of sample lesson plan on student’s achievement level. The study was conducted in the fall semester of the 2013-2014 academic year. The participants were 12 eight-grade students (four boys and 8 girls). In teaching the subject to the students, the sample lesson plan based on STEM approach was used in compliance with 5E learning cycle model.

2.1. Development of Instructional Design

A sample lesson plan were developed for the topic of acids and bases which will be an example for our science teaching programme based on STEM education. Specific activities in each discipline can be seen below:

1. Engagement Phase: In this phase, the aim is to determine the students’ prior knowledge and motivate them to engage in learning the topic.

   Science Discipline: Learners are clustered into groups of three. A case study questions are presented to the students in order to make them discuss with each other on acids and bases. Then, students are asked to share their thoughts about the case and various examples of acids and bases from their daily lives.

2. Exploration Phase: In this phase, each group is expected to record their observations and ideas. Then, they share their ideas with others and the teacher. The activities require the use of science process skills such as observing, measuring, classifying, inferring, predicting, communicating, defining operationally and collecting data during hands-on activities.

   Science Discipline: The following five experiments on acids and bases are applied on students:
   - The teacher gives some solutions used in daily life and a red litmus paper to each group. The students try to distinguish these solutions as acids or bases by using blue litmus paper. Then, students show that acids change blue litmus paper to red and red litmus paper remains the same. Bases change red litmus paper to blue and blue litmus paper remains the same as well.
   - Students design an experiment on the electricity of acid and base solutions.
   - Students measure the pH level of various matters by using pH scale and discuss the effects of pH level on matters and living organisms.
   - Students design an experiment to show that acid and base cause neutralization reactions when they are combined.
   - Students show the effects of acids and bases on various matters.

3. Explanation Phase: In this phase, the teacher explains the concept in accordance with students’ answers that they acquired as consequences of their previous experiences. They identify acids and bases by using the physical properties, the relation between acids and bases clarifies that the strength of acid solutions increases with the amount of H\(^+\) ions while the strength of base solutions increases with the amount of OH\(^-\) ions in the solutions. The teacher gives examples for acidic and basic substances in daily life, explains that solutions with a pH value lower than 7 is acid and a solution with a pH value higher than 7 is base, clarifies that a solution with a pH value equal to 7 is neither an acid nor a base but a neutral solution. Then, the teacher states that strength of an acid increases with a decrease in pH and strength of a base increases with an increase in pH, explains that NO\(_2\) and SO\(_2\) gases cause acid rains. Additionally, he/she presents scientifically correct explanation by using instructions based on computers and examples from daily life in order to make concepts more clear.
Technology Discipline: Students are taken into a computer laboratory to watch “Acids and Bases” animation, which can be found on Morpa Kampus web page (http://www.morpakampus.com).

4. Elaboration Phase: In this phase, students use their new knowledge in a different situation such as extending conceptual understanding, practicing desired skills, and reaching to meaningful understanding by using following disciplines:

Mathematic Discipline: Study questions about pH calculations are given to students and all of them are asked to draw graphics about pH levels of some acidic and basic matters.

Technology Discipline: Students are asked to create a slowmotion and a computer-based simulation about acid rain cycles using a guide prepared by the researchers.

Engineering Discipline: Students work in groups in the laboratory. They use their newly acquired knowledge to design a hand-made pH metre and conduct a project to protect objects and living organisms from the effects of acid rains.

5. Evaluation phase: After the implementation, an achievement test that assesses the students’ learning outcomes is applied to the learners in a 40-minute class session.

2.2 Data Collection Tool

A 10 item open-ended question survey was used in this research. At the beginning of the study the survey was completed by the students. It was used to determine their prior knowledge about acids and bases. At the end of the study, the survey was re-administered after the teaching intervention to the students. The test includes questions about the definition of acids and bases, the characteristics of acids and bases, strong and weak acids and bases, pH and pOH concepts, neutralization reactions and acid rains. A rubric was prepared to evaluate the result of each open-ended question. Each question was evaluated using a scale of 0-3 (0=completely wrong or unanswered, 1=mixture of correct and incorrect information given, 2= correct but incomplete, 3= completely correct). Two authors coded students’ responses to these ten questions independently and the percentage of codes having a kappa of 0.84 ranged from 41.2% to 100% depending on the question.

2.3 Data Analysis

The quantitative data was analyzed with descriptive statistics including means, standard deviations, and Wilcoxon Signed Ranks Test for Paired Samples non-parametric using the SPSS 20.00 program at the significant level of .05.

3. Results

For the first research question, descriptive statistics involving means and standard deviations were used to determine the students’ achievement levels. The results showed that the achievement mean scores of students’ on pre-test to post-test had increased from 9.75 (SD=3.04) to 23.25 (SD=2.89), which means that most students’ post achievement levels were near to acceptable level when considering the possible overall scores could range from 0 to 30. The post-test results (x=23.25, SD=2.89) also indicated that students gain the objectives of the topic on a level above average. The change in achievement scores from pre to post-test for all students is presented in Table 1.
For the second research question, Wilcoxon Signed Ranks Test for Paired Samples is accepted non-parametric because of the number of students and the p-value = 0.002 (<0.05) for the two tests that were used to determine whether there was a statistically significant difference between the pre and posttest results. The test results revealed that achievement level scores (z(12)= -3.063, p<0.01) of the students were significantly higher than the scores of students before instruction. The results are presented in Table 2.

Table 2. Wilcoxon Signed Ranks Test Results Between Pre-Test and Post-Test

<table>
<thead>
<tr>
<th>Measurement of pre and post-test</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative Ranks</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-3.063</td>
<td>0.002*</td>
</tr>
<tr>
<td>Positive Ranks</td>
<td>12</td>
<td>6.50</td>
<td>78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ties</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p≤.01, indicates a significant change from pre-test to post-test

4. Discussion and Conclusion

The effectiveness of the sample lesson plan that was developed by the researchers on 8th grade students’ achievement levels in terms of gaining the objectives in a secondary school science course was investigated in this study. This is a pilot study, which is applied to the small group of students before the main implementation. It is found that students had inadequate knowledge about acids and bases before the study but they managed to gain the learning outcomes in sufficient level after the implementation. However, it is thought that students’ mean score on achievement tests (x=23.25, SD=2.89) can be increased by using additional activities on the disciplines of STEM approach, seeing that the highest score of achievement test is 30. One of the reasons might be insufficient engineering activities in this study. Additional engineering activities should be applied using project based instructions with more interested students. Lantz (2009) stated that the engineering element of STEM education helps students explore mathematics and science in a more independent way, while helping them to develop the critical thinking skills that can be applied to all facets of their work and academic lives. Engineering is a method that students utilize for discovery, exploration, and problem solving.

One of the goals of STEM education is to raise interdisciplinary thinkers (Figliano, 2007). Four disciplines of STEM education combined to teach a science subject were used in the study. The results of this study are consistent with the study conducted by Becker and Park (2011). Their study showed that students’ achievement on the integrated concepts of STEM literacy showed large effect sizes. Science achievement presented a medium effect size while the technology achievement showed a large one. Also, Aurandt (2012) found that STEM education has been effective on learning and accomplishment of learning objectives. Raines (2012) remarked that student
participation in the first STEM summer bridge program on pre-college STEM majors affected academic performances positively.

This pilot study also stated that the subject of acids and bases can be completed in 12 lessons planned in the year plan of science course. Because of reasons mentioned above, the lesson plan for acids and bases can be extended during the practice of the course. Still, it is satisfactory to see that pilot study results were acceptable. Hence, it is hoped that this study will be helpful for researchers who study the instructional design of science materials and it will be beneficial for secondary science students and teachers by being a sample for STEM education.

References