The effect of open-ended science experiments based on scenarios on the science process skills of the pre-service teachers

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Abstract

The aim of the present study is to investigate the effect of laboratory applications based on scenarios on the pre-service Science teachers’ science process skills. The sample group of the study consists of a total of 85 pre-service teachers (45 for the experimental group, 40 for the control group) who are in their first year in the Science Education Program in a state university. The model employed in the research study was a semi-experimental one having a pre-test, post-test experimental group and control group. The experiments were conducted in the experimental group using scenario-based worksheets, whereas the control group was offered a close-ended experiment. In the study, the “Science Process Skills Test”, which was adopted by Aydoğdu (2006), was employed as a means of data collection. As a result of this study, it was found that the science process skill levels of the experimental group were significantly higher than those of the control group (p<.01). Accordingly, it can be argued that laboratory activities conducted with scenario-based worksheets are more effective than laboratory activities conducted with close-ended experiments in developing basic and integrated science process skills on the part of pre-service teachers.

Keywords: pre-service teachers, science process skills, open ended science experiments

1. Introduction

One of the basic aims of science education is to develop students who can undertake examinations, enquiries and research to meet the needs of the current age, who can relate their daily lives to the scientific situation, who can use scientific methods to solve the problems they encounter in every area of their lives, and who can have a scientific perception with regard to the world they live in (Tan and Temiz, 2003). To this end, students should be aware of the scientific research process. Scientific research develops the high level thinking skill of students such as by asking questions, making enquiry, solving problems and establishing communication (Cuevas, Lee, Hart & Deaktor, 2005). Science process skills are among the most frequently used high level thinking skills in the research process (Aydoğdu, Tatar, Yıldız-Feyzioğlu & Buldur, 2012). Science process skills should be acquired, not only by scientists, but by all individuals, since people who cannot use science process skills are hardly likely to be successful in life (Rillero, 1998). Ferreira (2004) reported the importance of science process skills in science education. Due to this importance, science education should be designed in such a way as to include an education in science process skills (Huppert, Lomask & Lazarowitz, 2002; Saat, 2004). Science process skills are defined as the tools needed to...
acquire world knowledge and to make this knowledge regular (Osborne & Fryberg, 1985; Ostlund, 1992), and are categorized under two groups - basic and integrated (Burns, Okey and Wise, 1985; Carey, Evans, Honda, Jay & Unger, 1989; NRC, 1996; Saat, 2004; Yeany, Yap & Padilla, 1984). Basic skills constitute the basis of integrated skills (Padilla, 1990; Rambuda & Fraser, 2004). The basic skills can be acquired by students from an early age, while integrated skills can be acquired from the first grade of primary school (Ergin, Şahin-Pekmez & Öngel-Erdal, 2005). Within this context, students are expected to have acquired integrated skills when they move into the secondary school. The acquisition of students’ science process skills in the secondary school is deeper than the primary school (Çepni & Çil, 2009).

The role of laboratories is important in the acquisition of science process skills on the part of students (Aktamış, Aydoğdu & Ergin, 2007). As is well known, laboratories play a central role in science education. Science educators report that learning tends to be more effective thanks to the use of laboratories (Hofstein & Lunetta, 1982). In addition to the aforementioned importance of laboratories, the experimental techniques used in laboratory applications are crucially significant. Many techniques are used in order to increase the effectiveness of laboratory applications. In parallel with modern learning approaches, the techniques used in laboratories have been transformed in recent years into high level structured activities based on open-ended research rather than teacher-centered ones (Hofstein & Mamlouk-Naaman, 2007). Herron (1971) (cited in Dana, 2001) categorized laboratory education into four groups based on their degree of openness (Table 1).

| Level of Discovery | Problems | Ways and Means | Answers |
|-------------------|----------|---------------|---------|
| 0                 | Given    | Given         | Given   |
| 1                 | Given    | Open          | Open    |
| 2                 | Given    | Open          | Open    |
| 3                 | Open     | Open          | Open    |

Table 1. Degree of Openness of Laboratory Education (Herron’s classification scheme)

Reference (Herron 1971, cited in Dana, 2001).

Worksheets can be seen to follow the numerical axis suggested by Herron depending on their degree of openness. Teachers can prepare worksheets at different levels of openness (at different levels on the numerical axis) from ranging from closed-ended worksheets to inquiry-based ones in line with their educational aim (Ergin, Şahin-Pekmez & Öngel-Erdal, 2005).

Figure 1 shows that closed-ended worksheets are at the 0th level, semi-open-ended work-sheets are at the 1st level, open-ended worksheets are at the 2nd level and inquiry-based worksheets are at the 3rd level (Ergin, Şahin-Pekmez & Öngel-Erdal, 2005). Closed-ended experiments are the ones designed in order to prove something (Çepni & Ayvacı, 2006). In such experiments, teachers are central, both for the dissemination of knowledge and the organization of methods (Kaptan, 1999). Traditional laboratories are of this type.

In semi-open-ended experiments, problem and method may be presented to students or problem, results and comments may be preserved, but purpose and method may be obscure (Ergin, Şahin-Pekmez & Öngel-Erdal, 2005). In the semi-open-ended experiment method, the open (deficit) parts of the experiment are expected to be completed by the students (Yenice & Aktamış, 2004).

Open-ended experiments are designed in such a way as to allow students to explore and invent (Ergin et al., 2005). This method allows students to choose experimental apparatus, to acquire and interpret data, and to determine the results. Therefore, with the open-ended experiment method, students are expected to develop their psychomotor abilities and such behaviours as thinking, deciding, making original implementations in line with their decisions, and making deductions in terms of the results obtained (Çepni & Ayvacı, 2006).
With regard to the inquiry-based experiment technique, students are given relatively few directions and are expected to undertake the experiment in an environment in which they have a good deal of responsibility (Leonard, 1989, cited in Domin, 1999). Students determine their problems and develop their own solutions using the inquiry-based experiment technique. Therefore this method has a significant place in science education (Hodson, 1990).

Using this technique, students are given a research problem and are expected to design their experiment, to gather data and to analyze them (Ergin, Şahin-Pekmez & Öngel-Erdal, 2005).

As can be seen in the relevant literature, laboratories play a central role in science education. In addition to the significance of laboratories in the teaching of science, the experimental techniques employed in such laboratories are also relatively important for the achievement of educative goals. In this respect, the aim of the present study is to investigate the effects of laboratory applications based on scenarios on the science process skills of pre-service Science teachers.

2. Methodology

2.1 Research design

The research was of a semi-experimental pre-test/post-test control group design.

2.2 Study group

The study group involved in the research was 85 first year students (45 experiment and 40 control group) being educated in the Department of Science Education of a state university in the 2011-2012 academic year.

2.3 Data collection process

In this study conducted within the scope of the General Physics Laboratory II module, experiments were conducted using worksheets based on scenarios in the case of the experimental group, while close-ended experiments were conducted in the case of the control group. In the implementation stage of the research, each group conducted 6 experiments over a 12 week period.

The “Science Process Skill Test” (SPST), which was adopted by Aydoğdu (2006) by examining studies in this field (Enger & Yager, 1998; Dana, 2001; Ergin, Şahin-Pekmez & Öngel-Erdal, 2005; Anonymous, 2006), was used as the data acquisition tool. This test consisted of nine multiple choice questions requiring the reasons for the answers given and seven scenarios. The maximum score of the SPST is 46, 18 marks from the multiple choice questions and 28 marks from the seven scenarios.

2.4 Data analysis

In terms of data analysis, the t-test was used for independent samples and the two-factor ANOVA test was used for the complex measurements involved in the comparison of pre-test and post-test scores obtained from the experimental and control groups.

3. Findings

The findings will be presented under two headings since the improvements of pre-service teachers in science process skills are examined separately with regard to basic skills and integrated skills.

3.1 Findings regarding basic science process skills

Table 2 shows the average and standard deviation values regarding pre-test and post-test scores of the pre-service teachers based on the questions about basic level skills on the science process skills scale.
Table 2. Average and standard deviation values regarding pre-test and post-test scores of basic level skills on the science process skills scale

| Group       | Pre-Test |       |       | Post-Test |       |       |
|-------------|----------|-------|-------|-----------|-------|-------|
|             | N        | M     | Sd    | N         | M     | Sd    |
| Experimental| 45       | 12.24 | 2.82  | 45        | 14.87 | 2.80  |
| Control     | 40       | 12.22 | 2.89  | 40        | 12.70 | 3.69  |

According to the t-test undertaken for independent samples in order to compare the average scores of participants in the experimental and control groups during the pre-test, no significant difference was found between the pre-test score averages of the pre-service teachers ($t_{(83)}= 0.031$, $p>.05$). However, a significant difference was found between the post-test score averages of the experimental and the control group in favour of the experimental group ($t_{(83)}= 3.07$, $p<.05$).

Table 3 shows the results of the two factor ANOVA regarding the significance level of the change in pre-test and post-test scores of the students in the experimental and control groups regarding basic level science process skills.

Table 3. ANOVA results of pre-test- post-test scores of basic level skills of science process skills

| Source                  | Sum of squares | df  | Mean of squares | F    | Sig. |
|-------------------------|----------------|-----|-----------------|------|------|
| Between-subjects        | 1076.21        | 84  | 62.96           |      |      |
| Group (Experimental/Control) | 50.60         | 1   | 50.60           | 4.09 | .046 |
| Error                   | 675.67         | 83  | 12.36           |      |      |
| Within-subjects         | 101.57         | 85  | 156.72          |      |      |
| Measure (pre-test-post-test) | 48.82        | 1   | 101.57          | 16.05| .000 |
| Group*Measure           | 48.82          | 1   | 48.82           | 7.71 | .007 |
| Error                   | 525.28         | 83  | 6.33            |      |      |
| Total                   | 1601.49        | 89  | 219.68          |      |      |

Table 3 shows that there are significant differences in the basic science process skills of students in the experimental and control groups between the pre- and the post-period of implementation. This indicates the joint effects of participating in different laboratory implementations (scenario-based and close-ended experiments) and the repetitive measurements (pre-test-post-test) of factors on the basic level science process skills of students ($F(1,83)=7.71$, $p<.05$). This finding indicates that laboratory activities conducted with scenario based worksheets are more effective than laboratory activities conducted using close-ended experiments in developing the basic level science process skills of pre-service teachers.

3.2 Findings regarding integrated science process skills

Table 4 shows the average and standard deviation values regarding the pre-test and post-test scores of pre-service teachers from the questions about integrated skills on the science process skills scale.

Table 4. Average and standard deviation values regarding pre-test and post-test scores of integrated skills on the science process skills scale

| Group       | Pre-Test |       |       | Post-Test |       |       |
|-------------|----------|-------|-------|-----------|-------|-------|
|             | N        | M     | Sd    | N         | M     | Sd    |
| Experimental| 45       | 12.76 | 3.64  | 45        | 18.62 | 3.99  |
| Control     | 40       | 12.07 | 3.78  | 40        | 13.40 | 5.05  |

According to the t-test undertaken for independent samples in order to compare the average score of participants in the experimental and control groups in the pre-test, no significant difference was found between the pretest averages scores of the pre-service teachers ($t_{(83)}= .84$, $p>.05$). However a significant difference was found between the post-test average scores of the experimental and the control group in favour of the experimental group ($t_{(83)}= 5.32$, $p<.05$).
Table 5 shows the results of the two factors ANOVA regarding the significance level of the change in pre-test and post-test scores of the students in the experimental and control groups regarding integrated science process skills.

Table 5. ANOVA results of pre-test- post-test scores of integrated skills of science process skills

| Source                  | Sum of squares | df | Mean of squares | F     | Sig. |
|-------------------------|----------------|----|-----------------|-------|------|
| Between-subjects        | 2458.20        | 84 | 394.09          |       |      |
| Group(Experimental/Control) | 368.92        | 1  | 368.92          | 14.66 | .000 |
| Error                   | 2089.28        | 83 | 25.17           |       |      |
| Within-subjects         | 1516.01        | 85 | 775.06          |       |      |
| Measure (pre-test-post-test) | 547.62        | 1  | 547.62          | 60.60 | .000 |
| Group*Measure           | 218.40         | 1  | 218.40          | 24.17 | .000 |
| Error                   | 749.99         | 83 | 9.04            |       |      |
| Total                   | 3974.21        | 89 | 1169.15         |       |      |

Table 5 shows that there are significant differences in the integrated science process skills of students in the experimental and control groups between the pre- and post-period of implementation. This indicates the joint effects of participating in different laboratory implementations (scenario-based and close-ended experiments) and repetitive measurements (pre-test-post-test) of factors on the basic level science process skills of students ($F (1,83)=24.17$, p<.05). This finding indicates that the laboratory activities conducted with scenario based worksheets are more effective than laboratory activities conducted using close-ended experiments in developing the integrated science process skills of pre-service teachers.

4. Conclusion and suggestions

Within the scope of this study, while no significant differences were found between the pre-test average scores in terms of the science process skills of students in experimental and control groups in terms of basic and integrated skills, a significant difference was determined between the post-test average scores in favour of the experimental group. On the other hand, there is a significant difference in the basic and integrated science process skills of students in the experimental and control groups following implementation. This indicates the significance of the difference between the pre-test and post-test average scores of students participating in different laboratory applications (scenario-based and close-ended experiment types). In other words, it can be said that laboratory activities conducted with scenario-based worksheets are more effective than laboratory activities conducted using close-ended experiments, in developing the basic and integrated science process skills of pre-service teachers.

Studies in the literature stress that open-ended experiments provide greater acquisition of science process skills than closed-ended ones (Aydoğdu, 2009; Başağa, Geban & Tekkaya, 1994; Gangoli & Gurumurthy, 1995; Hall & McCurdy, 1990; Knabb & Misquith, 2006; Krystylniaik & Heikkinen, 2007; Little, 2006; Myers, 2004; Myers & Dyer, 2006; Roth & Roychoudhury, 1993; Suits, 2004; Veath, 1988). Studies that have been conducted report that the use of closed-ended experimental methods has a limited effect on the acquisition of science process skills on the part of students (Aktamış, 2007; Aydoğdu, 2009; Kanlı & Yağbasan, 2008; Renner, 1986; Sevinç, 2008).

The results of the study indicate that the experiments conducted with regard to the acquisition of science process skills are important. However, the data obtained show that different experimental methods provide different skill acquisitions at different levels. In conclusion, the use of scenario-based worksheets in laboratory lessons conducted with pre-service teachers provided more improvement in the science process skill levels of pre-service teachers compared with the traditional approach. Therefore, it is suggested that scenario-based experiments should be incorporate into General Physics Laboratory modules for pre-service Science teachers. In this way, implementations can be related to everyday life and pre-service teachers can better develop their science process skills.

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