 제26권 제3호, pp. 260~266 (2007)

Understanding Science Experiments with Science Drama

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과학 연극 활동이 과학 실험의 이해에 미치는 영향

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국문초록

대개 학교에서 이루어지는 과학 실험은 추상적인 과학 지식이 실제에 어떻게 적용되는지를 보여주기 위한 것이다. 그러나 많은 경우 학습자들은 실험을 하더라도 그 실험이 어떤 의미를 가지고 있는지 이해하지 못한다. 이 연구는 초등 예비교사를 대상으로 하였으며 실험 활동과 관련된 과학사를 연극의 형태로 도입하여 실험 내용에 대한 이해를 증진시키고자 하였다. 먼저 전자기 유도에 관련된 몇 개의 실험을 실시한 후 패러데이의 전자기 유도 발견에 관한 짧은 과학 연극을 준비하고 실시하였다. 그리고 이러한 과학 연극의 도입이 이전에 실시한 실험 내용(실험 결과와 이에 대한 해석)을 이해하는 데 도움이 되는지를 알아보기 위해 실험 직후, 과학 연극 실시 직후 동일 검사지를 실시하여 비교 분석하였다. 또한 과학 연극을 실시하는 것이 과학 학습에 도움을 주는지에 대한 예비교사들의 의견도 설문을 통해 조사하였다. 연구 결과 과학 연극을 실시한 직후 이전에 실시한 실험의 내용을 이해하고 그 실험으로부터 얻은 지식을 적용하는 능력이 향상된 것으로 나타났다. 연극 공연자가 관람자에 비해 실험에 대한 이해가 더 많이 증가하였지만 통계적으로는 유의미한 차이가 없었다. 또한 80% 이상의 참여자가 과학 연극이 실험 내용의 이해에 도움이 되는 것으로 인식하였으며 공연자가 관람자보다 더 긍정적으로 인식하였다. 참여자들의 반응으로부터 어떠한 점에서 과학 연극이 과학 학습에 도움이 되는지, 과학 연극의 장점과 한계점이 논의되었다.

주요어 : 과학 실험, 과학 연극, 과학사

I. Introduction

The science and experiments taught at school are usually about established science, which has been developed over many years through the efforts of many people, so there is little room for students' debate. This might lead to the incorrect assumption that science is depersonalized or an objective copy of the truth. Clive Sutton (1998) pointed out that classroom talk would be more meaningful when it is about people and their thoughts: Why the problem mattered, what arguments they put forward, and what evidence they used.

Learners in school are exposed to a lot of ready made science and liable to get a distorted view in which the subject seems to be about certainties, and facts read off directly from 'the book of nature'. They may indeed experience it as a mass of given information rather than on-going discussion, unless the teacher can re-animate the doubt of the past and show how today's taken-for-granted knowledge was constructed (Clive Sutton, 1998).

How can we *re-animate* the process of past knowledge construction in the classroom? The first necessity might be knowledge of an idea's history. Many science

이 논문은 2005년도 춘천교육대학교 교내 연구비 지원에 의하여 연구되었음.
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educators have argued for the inclusion of science history in science teaching, not for history itself, but to improve the understanding of science. It provides knowledge on the nature of science, such as the tentativeness of science theory and experiments as trying explanations. It can also provide a specific concept development process, how the ideas were first developed (Wang & Marsh, 2002). An intelligible story of why a certain scientific concept was borne could facilitate students' assimilation of a concept as well as their understanding of the process of science. Science history could be incorporated in science teaching in many ways such as reading materials, discussion topics, and so on. One of those possible forms could be through science drama.

In science education, there have been some trials and studies on science drama, though it was not as many as other issues in science education. For example, 'Deciding evolution's place in the science curriculum (Bentley, 2000)', 'The story of vaccination against smallpox (Solomon, 1991)' tackle the nature of science through role play. 'Gene-ghost (Odegaard, 2003)' is a creative drama about the issue of biotechnology. Odegaard (2003) summarized these efforts and showed diverse possible types of science drama according to science education dimensions: science as product, the process and nature of science, science as an institution in society. He categorized science drama as explorative, semi-structured and structured and argued that pedagogical advantage of drama is to create non-authoritarian and creative learning environment. There could be many other criteria to discern the type of science drama in classroom. Yoon (2004) also categorized science drama according to it's theme to show there are many possible ways of using drama in science education : 'science concepts drama'- represent science facts or knowledge, 'science character drama'- show scientist's life story, 'science history drama'- show memorable scientific event or development process in history of science, 'science debate drama'- deal with social issue of science and technology, 'science expression drama'- focus artistic expression using science symbols or new technology. The science drama performed in this study dealing with Faraday's electromagnetic induction can be called a kind of 'science history drama' according to Yoon (2004)'s categorization and 'structured' one according to Odegaard (2003)'s, where pre-service elementary teachers wrote their scripts and acted for presentation.

What are the benefits of introducing this kind of drama in science education? Do they have some similarities or dissimilarities with traditional science teaching activities? Two factors were pointed out as characteristics of science drama (Yoon, 2006). One is its 'story', and the other is the 'live-ness' of its performance. Most science drama has a 'story', even when there are no words but only movements or gestures. The story consists of events, characters and settings arranged in sequence (Carter, 1993), usually enabling peoples' emotional participation. Due to its life-likeness, the story enables affective and empathetic learning. The second characteristic of science drama, the 'live-ness', comes from the use of the 'present' tense and the actions of participants. It unfolds before the eyes of students through their actions. This 'live-ness' in science drama, rather than the use of written texts or multi-media animations, could make students' participation and interactions with the story occur easily.

In this study, science history was introduced as a form of drama. It was assumed that science drama could bring pre-service elementary teachers' deeper understanding of their experiments by providing time for appreciation of the meaning of experiments and the reconstruction of their knowledge. So the improvement of cognitive understanding through this non-traditional activity was explored. Their understanding just after the experiments was compared with that after science drama performance. The participants' opinions regarding the use of science drama for their science learning were also investigated. Though there was some intention to make pre-service teachers aware of the possible use of science drama in their future classroom teaching, it was not directly dealt with in this study.

II. Process Overview

The participants were 7 classes of pre-service elementary teachers, totaling 220 students, and the study was conducted during their Elementary Science Method course. Some experiments, hands-on activities related to the primary science curriculum, and teaching methods were introduced. The relevance of electricity and magnetism was studied for two weeks. During the first week they did some experiments and during the second week science dramas were performed and discussed.

Three experiments were conducted. First, the students observed the changes in a compass needle when it was placed near a current carrying wire in various conditions. Second, they moved a magnet into and out of a solenoid to induce current and explored what creates more current. Third, they were shown a magnet falling slowly through a copper pipe and asked to make their own explanations using clues from the previous two experiments. After these activities, a short explanation of the history of electromagnetic induction was given by the instructor (researcher). That was about Oersted's discovery of a magnetic field around a current carrying wire, Sturgeon's making of electromagnets and Faraday's discovery of electromagnetic induction inspired by the previous two discoveries. A questionnaire was implemented to check their understanding of the experiments at the end of the class. The questionnaire consisted of seven questions, asking the results of the experiments and the meaning of their results. Three questions, in particular, on the third experiment, required the ability to apply knowledge from other two experiments. The classes were asked to properly refer to relevant experiments when explaining the phenomena of the slowly falling magnet. The pre-service teachers were then asked to create a ten-minute science drama related to these experiments and be prepared to perform it for the class during the second week. The instructor (researcher) provided an example of a synopsis and scene structure (Table 1) for the science drama, as well as the characters. The students could easily create scripts using the provided materials but were encouraged to be creative. They were instructed not to give much emphasis to props and costumes and that the memorization of scripts would not be necessary for this classroom performance.

Half of each class prepared their scripts and per formance cooperatively, the other half was the audience. During the second week, two ten-minute dramas were performed and the participants were encouraged to discuss the drama in a Q&A session after the performances. Once again, a questionnaire, similar to the previous one, was implemented to see if their understanding of the prior experiments had improved. The questionnaire also investigated their opinions on the use of science drama for their science learning and whether or not it helped their cognitive understanding of the experiments.

Table 1. Example scene structure given by the instructor

Scene No.	Title
1	Bookbinder's apprentice, poor Faraday
2	Oersted's discovery and Sturgeon's making of an electromagnet
3	Faraday's ten years of effort to induce electricity
4	Discovery of electromagnetic induction
5	Edison's praise of Faraday

1. Pre-service Elementary Teachers' Performance

The pre-service teachers' performances (14 as a total) could be grouped mainly into two styles. One style was everyday experiences relevant to electromagnetic induction. The students invited or visited Faraday to solve their everyday problems like a light of roller skate (Fig. 4). Sometimes, they became journalists and interviewed the scientist (Fig. 5). The second style was an unfolding story following a timeline and told by a narrator. Even though they had just one week for preparation, most performance teams researched the principle of electromagnetic induction, Faraday's life and historical discovery using books, articles, and internet resources. Some wanted information about Faraday's real instruments and the experimental methods of his time but there were few resources available, especially in Korean. Many teams tried to explain the scientific information in an easy way, so they prepared background pictures or flash animations, even real experiment video clips of their own to help the audience's understanding (Fig. 1). They made colorful

Fig. 1. Background flash animation

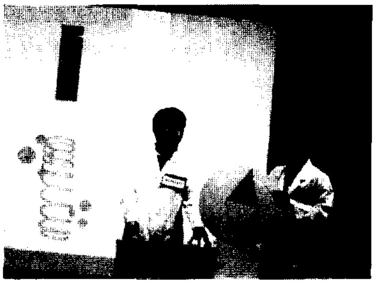

Fig. 2. Experiment equipment props

Fig. 3. Model of current using movement

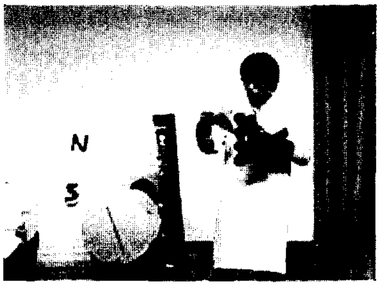

Fig. 4. Explanation on everyday curiosity (light of skate)

Fig. 5. Interview with scientist

Fig. 6. Questions after performance

props for experiment equipment such as a G-meter, compass and solenoid (Fig. 2). Sometimes they tried to model the information, using movement and actions, with the intent of helping the audience visualize abstract knowledge such as current in solenoids (Fig. 3). After the performance, they had a short amount of time for questions from the audience (Fig. 6). The instructor, as an audience member, asked questions to provoke thinking when there was a misunderstanding of scientific concepts.

III. Results

1. Understanding of Experiments

It was investigated if the pre-service teachers' understanding of experiments has been improved after the performance of science drama. Their understanding of experiments' results just after the experiments was compared with that after science drama performance through questionnaire. The statistics of the paired t-test show an increase in scores after the science drama (Table 2). The questionnaire was consisted of essay style questions so as not to greatly influence the students' memories. Q1 was two questions on experiment 1 (changes in a compass needle near a current carrying wire), first asking the result, second the interpretation of result. Q2 was also consisted of two questions on experiment 2 (moving magnet into and out of a solenoid to induce current). Q3 was three questions on experiment 3 (slowly falling magnet through a copper pipe). In Q3, it was asked to explain a slowly falling magnet using results of the experiment 1 & 2.

Table 2. Pre-post paired t-test results (N=209)

Test items	Time	Mean	SD	t	Significance level (Two tailed)
Q1 score	before	1.75	.478	−3.328	.001
	after	1.88	.372		
Q2 score	before	1.46	.604	−5.349	.000
	after	1.69	.521		
Q3 score	before	1.03	1.109	−4.455	.000
	after	1.35	1.087		
Total score	before	4.23	1.605	−6.511	.000
	after	4.92	1.432		

* The perfect score for Q1, Q2 was 2, and for Q3 was 3.

Two questions of Q3 were about if they can make proper connections between their explanation and the result of other experiments. The total score and Q1, Q2, Q3 each score also increased significantly after the drama performance. Notably, the score of Q3, which requires the ability to apply knowledge, increased the most (Table 2).

The performers' total scores increased more than the audience's (Fig. 7) but co-variance analysis, with the pre-test score as a co-variate, showed there were no significant differences between the performers and the audience (Table 4). Though there was no statistical difference, the larger improvements of performers' scores on Q2, Q3 should be noticed (Table 3).

2. Recognition of Science Drama

The pre-service teachers were asked if the drama helped their understanding of the prior experiments and why they thought so. About 84% of them gave positive answers on 5-point Likert type question (Table 5). The performers gave more positive responses (Table 6).

The participants were also asked to write the reasons why they thought the drama was helpful or not in their understanding of the prior experiments. Their reasons were very diverse. Many students recognized the educational value of the drama preparation and said that the preparation of the drama enhanced their understanding of the experiments (67 persons). That means that the preparation of the drama was recognized as a valuable learning process by the participants.

'To perform the drama, we needed more concrete knowledge of the experiments. I investigated and discussed it with friends in order to act properly. That helped my understanding a

Fig. 7. Changes in total score before and after the science drama

Table 3. Performers and audience scores

Test items	The performer (N=106)			The audience (N=103)		
	Time	Mean	SD	Time	Mean	SD
Q1 score	before	1.73	.508	before	1.77	.447
	after	1.88	.383	after	1.87	.362
Q2 score	before	1.39	.611	before	1.53	.591
	after	1.72	.530	after	1.67	.512
Q3 score	before	.94	1.085	before	1.12	1.132
	after	1.34	1.129	after	1.37	1.048
Total score	before	4.06	1.560	before	4.42	1.636
	after	4.93	1.520	after	4.91	1.344

Table 4. Co-variance analysis results between the performers and the audience

Dependent variable	Type Ⅲ Sum of squares	df	Mean square	F	Sig.
Total score	1.744	1	1.744	1.125	.290
Q1 score	3.506E-03	1	3.506E-03	.026	.873
Q2 score	.472	1	.472	2.024	.156
Q3 score	.202	1	.202	.238	.626

Table 5. Science drama for understanding of experiments

Responses		Frequency	%
Negative	1 (never helpful)	0	0
	2 (not helpful)	5	2.4
	3 (so and so)	31	14.8
Positive	4 (helpful)	138	66.0
	5 (much helpful)	34	16.3
Total		208	99.5

Table 6. T-test results between the performer and the audience

Group	M	SD	t	Sig.
Performer	4.07	.609	2.307	.022
Audience	3.86	.658		

lot. I will never forget this experience.'
'Writing the script gave me a deep understanding of the experiment. I studied the principle with enthusiasm and now I am very proud of our work.'

It was also mentioned that the props used in the drama allowed them to 'see' abstract science concepts (14 persons).

'Using props in the drama helped us to see and understand the abstract or invisible knowledge. The movement of electron demonstrated by an actor was quite helpful.'
'I understood the role of a G-meter when my friend acted as a needle (on a G-meter).'

The students (9 persons) also stated the context and background knowledge provided by the drama helped their understanding. Some of them (4 persons) recognized that the drama provided 're-construction' or 'reflection' time for their understanding.

'If we know who studied, how and for what purpose, we are more likely to accept scientific principles. The background of science can tell us the real meaning of the principle.'
'I did not notice the relationship between the two activities in previous lesson. Through the drama, I realized that they are closely linked. It was marvelous!'
'During the experiments, we were busy and focused to make sure that the results were correct. This time (during the drama) we could consider what the results meant, what the cause was and its effect.'
'For the audience, it provides time to recall and re-think the experiments.'

These responses show reasons for incorporating science drama into science classes. The students noticed how it could improve their learning. On the contrary, some students gave negative responses and recognized its weak points and limitations. Some (8 persons) said the drama was merely interesting and did not help their understanding. A few (4 persons) said that too much emphasis placed on interest can waste the opportunity for cognitive understanding. It was also pointed out that science drama requires a considerable amount of time and effort, so it is not always effective for increasing cognitive learning (8 persons).

'It (drama) is quite interesting and might be effective to motivate learning, but not effective for increasing knowledge or understanding.'
'It focused on 'interests', so that learning could not occur.'
'It requires too much preparation time. When considering the time and effort needed, it is ineffective for increasing knowledge and understanding.'
'It requires a great deal of effort and results in relatively little knowledge.'

It is worthwhile to note that the affective factor '*interest*' in the dramas was regarded as helpful as well as unhelpful for increasing cognitive understanding. Many students said science drama was helpful for their understanding of the prior experiments because it was interesting (20 persons) but just being '*interesting*' cannot guarantee that learning will occur (12 persons).

IV. Conclusion and Discussion

Many science educators have criticized 'cookbook' style experiments, and have argued the necessity of meaningful context to increase students' motivation and desire to learn (Jenkins, 1998). Science experiments and hands-on activities can give students concrete experience of a phenomenon but learners do not necessarily understand what the results means, why the experiments are important even it is relevant with historical discoveries.

In this study, science history was introduced to pre-service elementary teachers' class as a form of drama to give the idea of how the experiments were developed in science history. It was assumed that science drama could bring pre-service elementary teachers' deeper understanding of their experiments by providing time for appreciation of the meaning of experiments and the reconstruction of their knowledge. It was explored whether this type of science drama could enhance cognitive understanding of prior experiments and the participants' own opinions regarding the use of science drama were also investigated.

Pre-service elementary teachers' understanding of prior experiments increased significantly after the drama. The scores of three questions on three experiments all increased. Though the performers showed more increase than the audience, there was no statistical difference between them. The participants showed an overall positive attitude to science drama. About 84% of them thought the drama was helpful in their understanding of the experiments. The performers thought the drama was more helpful than the audience did. The participants noticed ways it could assist their learning. They recognized the preparation of the drama as a learning process and they could 'see' the science concepts through the use of props or performers' actions. The drama also provided background knowledge and 're-construction' or 'reflection' time for understanding. On the contrary, some participants gave negative responses and recognized its weak points and limitations. Too much emphasis on interest can waste a cognitive understanding opportunity and it could be ineffective considering the input, effort and time required.

As noted in this study, science drama can be combined with traditional teaching methods like experiments or hands-on activities. The first reason we try that combination is it provides human story of science, how the experiments and ideas were developed in science history. This kind of humanistic approach has been emphasized by recent 'science for all' agenda (Donnelly, 2004). As science educator, I hope this humanizing effort would be harmonized with or even enhance science content learning as we still have a body of knowledge to teach. So my underlying question is this: Does this humanizing effort add another dimension to traditional science learning or can it be also helpful to science knowledge learning? In other words, Is the science drama used in this study just for adding 'fun' or adding 'another human story' to be learned apart from science learning or can it be helpful also for science content learning? If it provides no room for science knowledge learning, it will be more difficult to be used widely. The result of this study did not show detailed process, but implicated it could contribute better understanding of science content knowledge. I suggest science drama or any other humanizing effort should be implemented in a way that it can enhance the quality of scientific knowledge learning, not as another independent dimension. More trials and efforts of science educators will make the use of science drama possible in variety settings.

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