Public Scientific Web-Lectures: Tracing and Supporting Learning and Transfer

Shulamit Kapon
Weizmann Institute of Science
shulamit.kapon@weizmann.ac.ill

Uri Ganiel
Weizmann Institute of Science
uri.ganiel@weizmann.ac.il

Bat-Sheva Eylon
Weizmann Institute of Science
bat-sheva.eylon@weizmann.ac.il

Abstract
This paper presents preliminary results of a learning experiment designed to trace the learning process that takes place in public scientific web-lectures accompanied by mediating learning activities. Fourteen students from the pre-academic center (Mechina) at the Technion Israel Institute of Technology were assigned to two groups. Each group was engaged in a 2 day learning cycle that involved watching 2 web-lectures, each on a different topic in physics. Each group completed a series of collaborative activities on one of these lectures. The activities dealt with scientific argumentation and analogical reasoning. The results show (1) growth in scientific knowledge independent of the lecture subject, (2) growth in understanding of the nature of science (NOS) and a transfer of awareness of the NOS.

Keywords: web-lectures, learning, argumentation, popular science, nature of science (NOS).

Introduction
In the last few years, there has been a considerable increase in public scientific lectures given by distinguished scientists. Many of these lectures are available on the web (e.g."'Shomu Shamaim' Lectures,"; "TAU astronomy club,", etc), and therefore can potentially be used for instructional purposes in the classroom.

Within a limited time frame, these lectures attempt to explain or give an idea or flavor of innovative and complex ideas in science to audiences that lack sufficient background knowledge. Can these web-lectures be used as an instructional source? What kind of learning do these lectures induce? Can we support this learning?

This study was motivated by the design and implementation of a long distance computerized course for physics teachers on early 20th century physics (Kapon, Ganiel, & Eylon, in press). The course included 3 public web-lectures on contemporary physics topics that were accompanied by collaborative activities that dealt with the scientific content and the nature of science (NOS) (Lederman, 1992) reflected in each lecture. The activities had two main foci: (1) the scientific arguments that were presented in the lecture. (2) the analogies and metaphors that were used by the lecturer. The teachers reported that the integration of public lectures on contemporary physics into the course was important, and that the accompanying activities, especially the argumentation activity contributed to enhancing their understanding (Kapon et al., in press). These remarks were backed by the teachers' performance on the weekly assignments. The learning experiment that is described in this paper was designed to better understand the specific contribution of the lectures and each of the activities, and to try to literally trace the learning process that took place.

The Collaborative Learning Activities: Arguments and Analogies

Theoretical Motivation

The notion that active engagement in argument building supports knowledge integration and understanding is well-documented in the literature (e.g., Bell & Linn, 2000; Wiley & Voss, 1999). Bell and Linn also presented some evidence that engaging students in argument construction enhances their understanding of the Nature of Science.

The analogical approach has been identified as a central explanatory element in public scientific lectures (Kapon, Ganiel, & Eylon, in press), and in popular scientific writing in general (Funkhouser & Maccoby, 1973; Yore, Hand, & Florence, 2004). Analogical reasoning is often conceptualized as being inferred by a mapping between the two parallel structures: source and target. The inference is reached through the parallel relations (Gentner, 1983; Gentner & Holyoak, 1997; Hesse, 1966; Holyoak & Thagard, 1997).

Description of the Activities

Active construction of the scientific arguments: The activity involves decomposition of the lecture into distinct arguments in several steps: (1) identifying each claim in the lecture and relevant examples, (2) constructing the evidence by: (a) describing the relevant results from the experiments and observations that were presented as support, (b) listing the relevant scientific principles that were presented while adding the missing pieces, (c.) justifying why a&b support the claim. A detailed description of this activity appears in (Kapon et al., in press). Each phase of the activity (1, 2a, 2b, 2c) started with individual work, followed by a group discussion and a class discussion that changed and/or refined the outcomes of the individual activity. The activity ended with a class discussion on the scientific method as it was reflected in the lecture.

Regeneration of analogical inferences: The participants were asked to explicitly map the source and target elements of each analogy, and to generate an explanation according to the resemblance relations between the source and target. Then they were asked to define the limits of the validity of the analogical resemblance. This activity also had an individual phase that was followed by group and class discussions.

Method

Participants

Fourteen students, who had just passed their pre-academic courses in mathematics and physics (Mechina) at the Technion, the Israel Institute of Technology, took part in the study and were paid for their time. These young adults' knowledge of physics and mathematics is equivalent to the knowledge of high school graduates who chose to major in physics and mathematics. The participants were assigned to 2 groups according to their psychometric scores and the Mechina final grades in physics and mathematics, so that the level of the students in both groups was similar.

Setup

During the experiment the participants watched 2 web-lectures that presented 2 different advanced topics in physics in a popular manner, one in the domain of quantum mechanics (Lecture A) and one in the domain of astrophysics (Lecture B). Each lecture was about an hour long and was given by a different lecturer. Both lecturers are acknowledged to be excellent public scientific lecturers. The participants were also engaged in collaborative learning guided by generic activities that processed *one* of the lectures (6 hours). The experimental setup is presented in Table 1.

Tracing the learning

- Each participant took knowledge tests on each lecture (at 3 points in time on one lecture – phase 2, 4, 6 of Table 1; and at 2 points in time on the other lecture – phase 2,8 of Table 1). The knowledge tests had 6 questions on each lecture. The questions dealt with the scientific knowledge that was presented in the lecture. It should be stressed that these questions required more than *knowledge telling*. They required *knowledge transferring* (Scardamalia & Bereiter, 1987), because the learners had to generate novel connections between the different pieces of information that were presented as well as their own personal knowledge in order to provide a full answer (e.g. what are the scientific claims that are supported by the results of the Aharonov-Bohm experiments, and why?)

Table 1. Experimental setup

Phase (time spent in hours)	Group 1 (N=7)	Group 2 (N=7)
1. *NOS attitude questionnaire (0.5)*	General	General
2. *Knowledge tests - science (1)*	Lecture A & Lecture B	Lecture A & Lecture B
3. Individual viewing a web-lecture, while filling out a guided summary worksheet (2)	Lecture A	Lecture B
4. *Knowledge tests - science and NOS (1)*	Lecture A	Lecture B
5. Collaborative learning guided by generic activities (6: argumentation-4.5, analogies-1.5)	Lecture A	Lecture B
6. *Knowledge tests - science and NOS (1)*	Lecture A	Lecture B
7. Individual viewing a web-lecture, while filling out a guided summary worksheet (2)	Lecture B	Lecture A
8. *Knowledge tests - science and NOS (1)*	Lecture B	Lecture A
9. *NOS attitude questionnaires (0.5)*	General	General
10. *Reflection (0.5)*	General	General

- The knowledge tests also included a question about NOS: “What are the aspects of the scientific method (how science is ‘done’) in this lecture – support your answer with specific examples from the lecture”. The participants answered this question twice on the first lecture (phase 4&6 of Table 1), and once on the second lecture (phase 8 of Table 1).
- The questionnaire regarding attitudes towards NOS was adapted and translated into Hebrew from two existing NOS attitude tests: VASS (Halloun & Hestenes, 1998) and VNOS-C (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). It included 12 questions, each presenting two competing views. The participants were asked to express their own opinion on a Likert scale ranging from 1-7 that started with one view and ended with the competing view.
- The students’ group work and class discussions were recorded. The qualitative analysis is in progress. This paper presents the preliminary results of the quantitative analysis of the questionnaires and the tests.

Analysis

A rubric for evaluation of the knowledge tests was designed. The tests were graded according to this rubric. 10% of the tests were independently double checked by 2 experts according to the rubric. The difference between grades was less than 10%. The results of all the tests were analyzed using repeated measures multiple analysis of variance (MANOVA). Although the repeated measures procedure enlarges the number of observations and the degrees of freedom of the analysis, we are aware that the small sample limits the validity of the findings.

Results and Discussion

Learning Science

Learning curve. Can we trace an improvement in the scientific knowledge in each part of the intervention? Is there a difference between the lectures in this respect?

The learning curve of scientific knowledge in each lecture is presented in Figure 1. Three average scores on the knowledge tests on each lecture (Lecture A / Lecture B) are presented: (1) before the intervention (phase 2 of Table 1 – 'Pre'), (2) after watching a lecture and summarizing it in the guided summary format (phase 4 of Table 1 – 'Watching'), (3) after the collaborative learning session (phase 6 of Table 1- 'Studying').

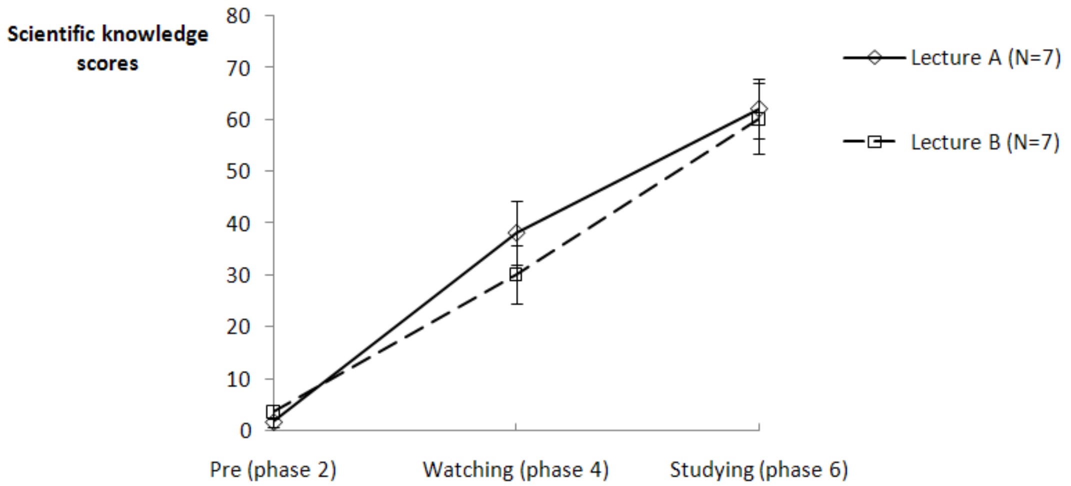

Figure 1. Learning curves of scientific knowledge

As Figure 1 reveals, the learning curves of both lectures are almost the same. This finding is statistically significant as the repeated measures process revealed no interaction between the lectures and the intervention phase ($F_{(2,24)}=0.769$, $p=0.475$). This is not a trivial outcome as each lecture presented a different subject in physics and was given by a different lecturer. The statistical calculation of the repeated contrasts between each two sequential phases of the intervention reveals that each made a significant contribution to the participants' knowledge of science (Pre-Watching: $F_{(1,12)}=64.545$, $p<0.001$; Watching-Studying: $F_{(1,12)}=41.812$, $p<0.001$). An examination of each specific question's repeated contrast between the 'Watching' and 'Studying' phases revealed significant learning gains on questions that were connected to the argumentation activity, whereas the questions that required analogical explanation did not show a significant gain after the formal learning process. This finding suggests that the argumentation activity was more fruitful than the analogy activity, and requires further study using a qualitative analysis of the discourse during the activity, in order to better understand this phenomenon.

Transfer. In order to determine whether the formal learning of one public scientific lecture affected self acquisition of scientific knowledge from another public scientific lecture the following comparison was conducted. Each group took a knowledge test on both lectures before the intervention (phase 2 of Table 1). Each also took the knowledge tests on both lectures after watching and summarizing each in the guided summary format (phase 4 and 8 in Table 1). However, Group 1 completed phase 8 of the study on Lecture B after they had studied Lecture A, and Group 2 completed phase 8 on Lecture A after formally studying Lecture B.

No significant interaction was observed between the scientific knowledge scores of the each lecture and the group identity ($F_{(1,12)}$=0.342, p=0.570).

Nature of Science (NOS): Knowledge of NOS

Learning curve. Does exposure to public scientific lectures influence knowledge *about* science (NOS)? Does the suggested activity contribute to this knowledge? Is there a difference between the lectures in this respect?

The learning curve of the NOS knowledge in each lecture is presented in Figure 2. Two average scores for the NOS question on the knowledge tests for each lecture (Lecture A / Lecture B) are presented: (1) after watching a lecture and summarizing it in the guided summary format (phase 4 of Table 1 – 'Watching'), (2) after the collaborative learning session (phase 6 of Table 1- 'Studying').

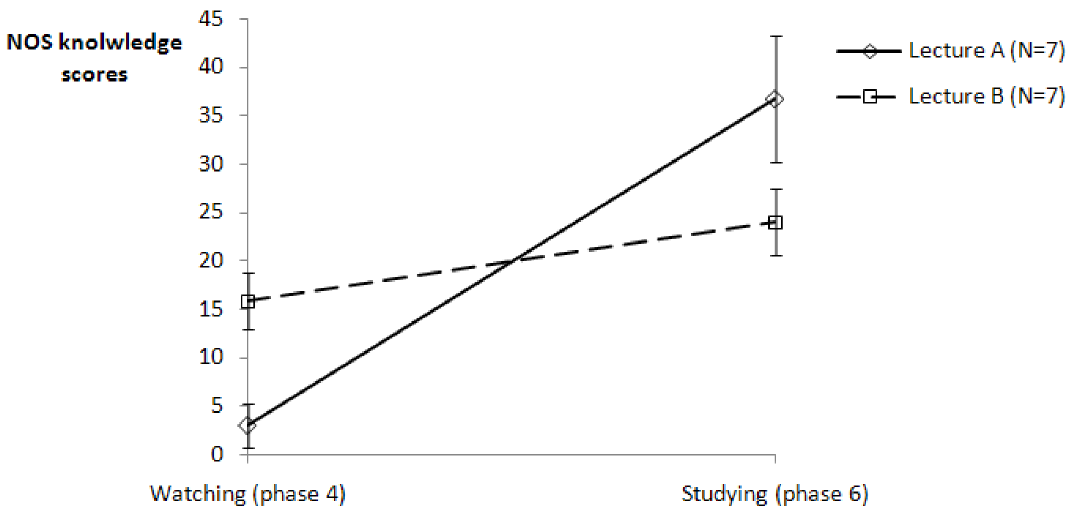

Figure 2. Learning curves for NOS knowledge

Figure 2 as well as the repeated measures procedure reveal that the formal learning phase contributed to awareness of the aspects of the scientific method ($F_{(1,12)}$=27.624, p<0.001). Nevertheless, Figure 2 shows that the learning process gains were much greater in the astrophysics lecture (Lecture B), as shown by the significant interaction between the 'lecture' and the 'learning gains' ($F_{(1,12)}$=10.236, p=0.008). This result can be interpreted in terms of the different ways each lecturer dealt with the NOS. The astrophysics lecturer (Lecture B) presented features of NOS explicitly, and spent time talking about them, while the quantum lecturer did not mention these aspects explicitly at all, although they could be inferred from his lecture. Therefore the formal learning phase of NOS was much more apparent in lecture A.

Transfer. Does the suggested activity on one lecture influence sensitivity to the Nature of Science aspects in another lecture?

Group 1 answered the NOS question in phase 4 of Table 1 ('Watching') regarding Lecture A. In phase 8 ('Watching') the group members did the same for lecture B, only this time, they answered after the activity (phase 5 in Table 1) on Lecture A. Group 2 did the same but answered phase 2 for Lecture B, and phase 8 for Lecture A after the activity (phase 5 in Table 1) on Lecture B. The repeated measures MANOVA revealed a significant interaction between the group and the scores for knowledge of NOS in each lecture ($F_{(1,12)}$=5.223, p=0.041). This can be interpreted as a transfer, where the suggested activity on one public scientific lecture affects awareness of the NOS in another scientific lecture. Figure 3 presents the grade of the NOS question in Lecture A and in Lecture B, for both groups. It is clear from this figure that the processing of one lecture (using the activities of phase 5 in Table 1) improved the scores of the NOS question for the second lecture no matter which lecture was studied first, although the lectures were different in terms of the explicitness of their references to NOS.

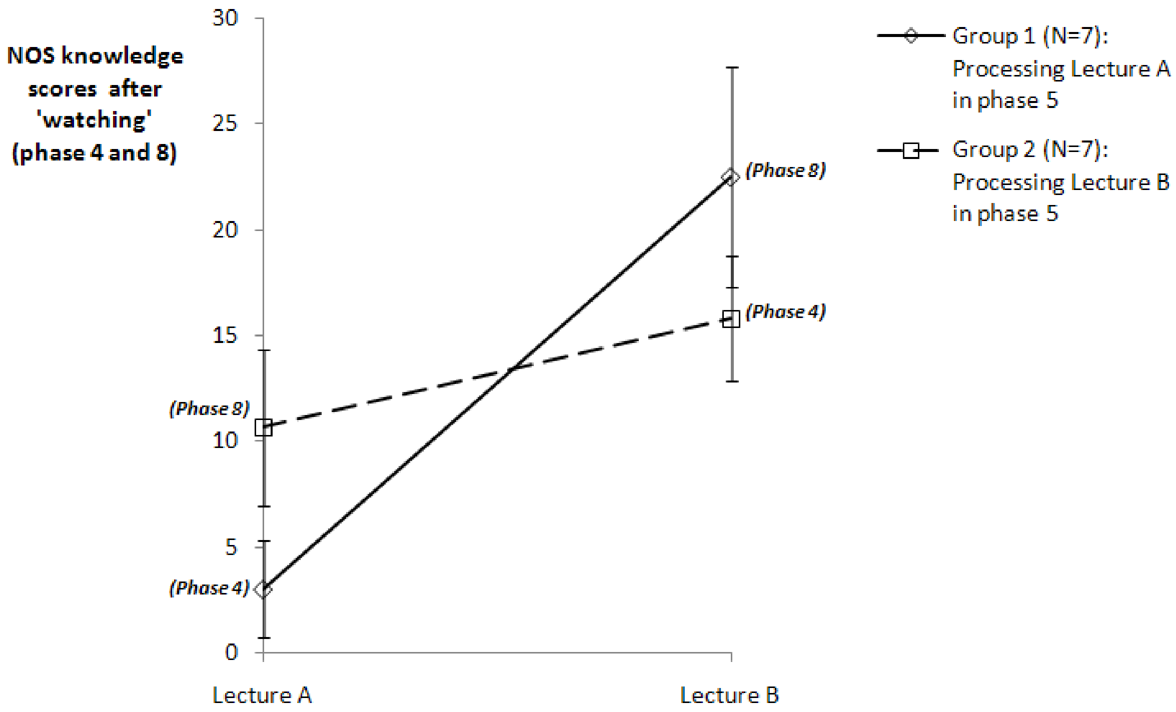

Figure 3. Tracing the transfer of NOS knowledge

Attitudes towards science. The comparison of attitudes towards science and scientific methods before and after the intervention (phase 1 &8 in Table 1) shows no change ($F_{(1,12)}$=0.516, p=0.486).

Conclusions and Implications

The above analysis shows that public scientific web lectures can be used as an instructional resource for scientific knowledge. Two different public scientific lectures showed the same learning curve. Learning of scientific knowledge was traced after watching two lectures, and was enhanced by generic collaborative activity that focused on scientific argumentation. The results suggest that these lectures and the accompanying activity can also be used as an instructional resource for teaching the Nature of Science (NOS). Not only was awareness of aspects of the scientific methods in one lecture enhanced after the collaborative activity, it was transferred to another lecture that was not processed. This transfer was independent of the content of the specific lecture that was processed (both groups demonstrated transfer). The findings also suggest that explicit (rather than implicit) presentation of NOS aspects in a popular scientific lecture results in better recall of these aspects. Further qualitative analysis is needed in order to better understand the contribution of the active construction of arguments to understanding, and to decipher the difficulties linked to the explicit mapping of analogies.

Caution should be exercised when attempting to generalize the conclusions given the small size of the experimental group. Nevertheless, the findings suggest that public scientific web lectures, which have increasingly become available free of charge on the web, should be seriously considered as an instructional resource for scientific knowledge and as an interesting context to teach NOS and scientific argumentation. Moreover, active engagement in argument building supports knowledge integration and understanding of the scientific knowledge that was presented in the lecture.

References

Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: Designing for learning from the Web with KIE. *International Journal of Science Education, 22*(8), 797-817.

Funkhouser, G. R., & Maccoby, N. (1973). Tailoring science writing to the general audience. *Journalism Quarterly, 50*, 220-226.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7*(2), 155-170.

Gentner, D., & Holyoak, K. J. (1997). Reasoning and learning by analogy: Introduction. *American Psychologist, 52*(1), 32–34.

Halloun, I., & Hestenes, D. (1998). Interpreting VASS dimensions and profiles. *Science & Education, 7*(6), 553-577.

Hesse, M. B. (1966). *Models and analogies in science*. Notre Dame, IN: University of Notre Dame Press.

Holyoak, K. J., & Thagard, P. (1997). The analogical mind. *American Psychologist, 52*(1), 35-44.

Kapon, S., Ganiel, U., & Eylon, B.-S. (in press). Explaining the unexplainable: Translated scientific explanations (TSE) in public physics lectures. *International Journal of Science Education*.

Kapon, S., Ganiel, U., & Eylon, B.-S. (in press). Scientific argumentation in public physics lectures: Bringing contemporary physics into high school teaching. *Physics Education*.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Scardamalia, M., & Bereiter, C. (1987). Knowledge telling and knowledge transforming in written composition. In S. Rosenberg (Ed.), *Advances in applied psycholinguistics* (Vol. 2, pp. 142-175). Cambridge: Cambridge University Press.

'Shomu Shamaim' Lectures. Retrieved November 9, 2008, from http://community-youth.huji.ac.il/program2.asp?cat=102&in=0

TAU astronomy club. Retrieved November 9, 2008, from http://astroclub.tau.ac.il/

Wiley, J., & Voss, J. E. (1999). Constructing arguments from multiple sources: Tasks that promote understanding and not just memory for text. *Journal of Educational Psychology, 91*, 301-311.

Yore, L. D., Hand, B. M., & Florence, M. K. (2004). Scientists' views of science, models of writing, and science writing practices. *Journal of research in science teaching, 41*(4), 338-369.