Explanatory Framework for Popular Physics Lectures

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Abstract. Popular physics lectures provide a 'translation' that bridges the gap between the specialized knowledge that formal scientific content is based on, and the audience's informal prior knowledge. This paper presents an overview of a grounded theory explanatory framework for Translated Scientific Explanations (TSE) in such lectures, focusing on one of its aspects, the conceptual blending cluster. The framework is derived from a comparative study of three exemplary popular physics lectures from two perspectives: the explanations in the lecture (as artifacts), and the design of the explanation from the lecturer's point of view. The framework consists of four clusters of categories: 1. Conceptual blending (e.g. metaphor). 2. Story (e.g. narrative). 3. Content (e.g. selection of level). 4. Knowledge organization (e.g. structure). The framework shows how the lecturers customized the content of the presentation to the audience's knowledge. Lecture profiles based upon this framework can serve as guides for utilizing popular physics lectures when teaching contemporary physics to learners lacking the necessary science background. These features are demonstrated through the conceptual blending cluster.

Keywords: explanations, popular science, lectures, physics education, contemporary physics, informal science education, conceptual blending.
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INTRODUCTION

The following analysis is part of a study which explores the features, design, and learning outcomes of explanations in popular physics lectures. These scientific explanations are interesting since they provide a 'translation' that bridges the gap between the specialized knowledge that formal scientific content is based on, and the audience's informal prior knowledge. We term these explanations TSEs, Translated Scientific Explanations, as they translate the scientific findings which emerge from the context of specialized knowledge and vocabulary into lay language without corrupting their meaning. The noun 'translation' has been used explicitly when referring to popular scientific writing [1].

The study involved a comparative examination of three exemplary popular physics lectures that were given by practicing physicists known to be excellent popular lecturers. The lectures are explored from three perspectives: the explanations in the lecture (as artifacts), the design of the explanation from the lecturer's point of view, and the learning that takes place by the audience. An explanatory framework for popular physics lectures, based upon the first two perspectives was developed. The paper presents the framework briefly and focuses on one of its main features: a cluster of categories that is referred to as the conceptual blending cluster.

The process of conceptual blending, or blending, is a fundamental cognitive process, characterizing (as a prerequisite) many cognitive phenomena, including categorization, generation of analogies and metaphors. Conceptual blending processes yield a new conceptual structure through composition, completion, and elaboration of inputs and existing schemes. Such a new conceptual structure is original as it is not present in any of the inputs [2].

Good popular physics lectures can be used as an instructional source of contemporary scientific ideas for audiences that lack a formal scientific background (e.g. high school students). The TSE explanatory framework may be used to create a lecture profile that can highlight the need for mediation tools and help better incorporate contemporary science through these lectures into high school instruction and learning [3]. The analysis of exemplary lectures can also enrich our understanding of how to craft explanations, especially abstract and complex ideas, where the students cannot have the entire necessary background.

Previous studies of scientific lectures in general aimed to provide a list of principles for the good lecturer (e.g. [4]). However, the explanatory view, especially in a popular scientific lecture, still needs to be explored. Physics provides a major challenge for popularization, as it is the most hierarchical of the natural sciences. The fact that physics progress and achievements during the last 100 years are hardly ever included in most high school curricula may be attributed to this feature.

METHODOLOGY

The data sources included three videotaped exemplary popular physics from different domains of physics, and three stimulated-recall interviews [5] with the lecturers. The lectures were selected using criteria that considered content, explanations, and lecturer.

The analysis was carried out using a grounded theory approach resulting in a hierarchical theoretical categorization induced from the data [5] [6], in the following manner: Lectures were segmented thematically (content) and structurally (e.g. analogy/organizational means, etc). Analysis unit varied from 20 seconds to 3 minutes. Interviews were studied through a mapping analysis [5]. An iterative comparison of the analysis of the lectures and the interviews, and the relevant ideas from the literature (e.g. research on analogies) yielded a grounded theory explanatory framework of TSE's in popular physics lectures.

RESULTS AND DISCUSSION

A grounded theory explanatory framework emerged from the analysis. This framework demonstrates that TSEs are derived from four clusters of categories. The categories connect the emerging theory (category definition) to the data (all the instances for this category in each lecture). The following four clusters of categories were common to all three lectures:

1. Conceptual blending - Explanatory elements that explain the novel in terms of the known. A characteristic category is the metaphor.
2. Story - Elements that deliver scientific ideas through means that are common in literature (fiction). A characteristic category is the narrative.
3. Content - Elements that reflect a judicious choice of content: what to include, what to omit, and means to achieve this goal. A characteristic category is the selection of topics.
4. Knowledge organization - Elements that manage knowledge. A characteristic category is structure.

Table 1 defines each category of the conceptual blending cluster, and presents a list of the number of instances of each category in every lecture. Examples are presented below.

TABLE 1. Definition of Categories Forming the Conceptual Blending Cluster, and the Number of Various Instances of Each Category in Every Lecture: Q= Quantum Physics, P= Particle Physics, A= Astrophysics.

Category	Definition	Q	P	A
Positive analogy	A systematic mapping between two situations: target (the novel situation) and source (the familiar one). The mapping is governed by causal, mathematical, and functional interrelations [7] that the two situations share [8].	2	1	5
Negative analogy	The analogy consists in properties or relations that the source and target do not share [8].	2	-	1
Bridging Analogy	Intermediate analogy between source and target [9].	1	-	-
Visual Analogy	Graphical resemblance between analogical elements, where a transfer of the relations occurs in similar visualizations (source-target) [10].	1	2	3
Metaphor	Structuring one concept in terms of another. Unlike analogies, metaphors do not necessarily map source-target directly; similarities can be associative [11].	2	-	2
Category Extension	Categorization is a classification and labeling of things into groups on the basis of their properties [12]. Extending a category means enrichment of its properties while retaining its original characteristics [2].	1	3	-

To illustrate some of the categories forming the conceptual blending cluster, we present examples from one lecture - "Quantum mechanics in a nutshell" [13]. The lecturer tried to explain that a quantum particle evolves through many parallel histories (can be in many places simultaneously), and its behavior at a given time is the sum of these histories. This peculiar behavior takes place under very restrictive conditions: the quantum particle cannot "leave a mark" (a proof of its passing) in any of the parallel paths. The lecturer stressed that this peculiar behavior is documented experimentally (the Aharonov Bohm effect was presented).

The lecturer said that although electrons move in a conductor like cars move on a road, a car can never be on two roads at the same time while an electron can, under the right conditions (small dimensions, low temperature, and "no mark left" – as in the "Aharonov Bohm" device). This is a negative analogy (Table 1). There is a direct mapping between source and target but the correspondence is between opposite relations (the ability to be in two places in the same time vs. not being able to do that).

This mapping was also cued graphically as depicted in Figure 1, which shows some of the illustrations that were used in this context. Figure 1 is an example of a visual analogy (Table 1). The graphic resemblance leads to a transfer of relations.

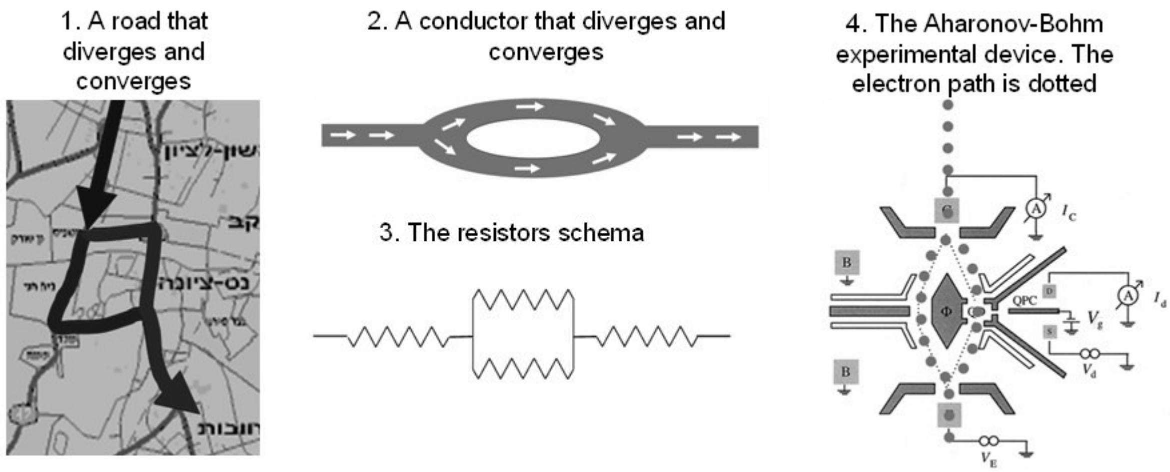

FIGURE 1. Visual Analogy – Excerpts from the Quantum Mechanics Lecturer's PowerPoint Presentation [13].

What about the phrase "leave a mark"? A child with dirty shoes leaves marks on the floor… This is a metaphor (Table 1) because one concept was structured in terms of another.

The lecturer presented sound waves as a known example of a wave that propagates through many paths simultaneously, stressing that the behavior of sound at a given point (e.g. our ear…) is the sum of all these “parallel histories”. Immediately afterwards he made a category extension (Table 1): He considered particles as waves, while stressing the similarities under the necessary conditions.

The lecturers regarded all the conceptual blending elements as 'analogies'. All of them stressed that these 'analogies' are the most important explanatory mechanism in popular scientific explanations and the most challenging and time consuming element to craft: *“It can take days, but I know I must have an analogy there, something that will connect them to what I'm saying. Sometimes I drop a whole subject if I do not find the right analogy…people won't understand me, and it will be just empty words”* (interview).

Table 1 shows that conceptual blending elements were present in all three lectures. However, the degree of usage differed, and a lecture profile could be created. The content of the quantum mechanics lecture was the most distant from the audience's background and the most abstract one. This lecture was the richest in conceptual blending different category instances. The particle physics [14] lecture presented a historical and phenomenological survey and its content was the least abstract of all the three lectures. This lecture used only a small number of conceptual blending elements. We think that when the degree of abstraction of the subject is high the use of blending categories becomes more frequent. However, this claim requires further investigation. One could argue that this difference is due to the lecturer's style. However, the content of popular lectures that are delivered by practicing physicists is usually connected in some way to the lecturer's expertise. Clearly the lecturer’s style plays its part, but one cannot exclude the influence of the subject that is presented.

The literature [2], [7], [11] suggests that conceptual blending categories provide a way to understand an unfamiliar or novel idea through the use of terms and inner connections of familiar situations or processes. This is achieved through an appeal to the following: a. visual resemblance, as in the visual analogy category; b. proximity of meaning, as in the category extension category; c. proximity of process, as in some of the positive analogy, negative analogy, and metaphor categories, especially in the instances where the source and the target are distant. This cluster's categories therefore expand available prior knowledge resources.

However, can listeners indeed decipher the information that lecturers provide through conceptual blending? Our findings (to be published elsewhere) show that often they do not. This is in accordance with the literature. For example, work on instructional use of analogies (e.g. [15]) suggests that to augment learning from popular lectures, mediation is needed.

Distant source-target instances can create misconceptions due to inappropriate mapping and deduction. This may suggest that explicit mapping and a definition of constraints may be necessary when the lecture profile shows high use of conceptual blending categories.

Although the conceptual blending elements are important, they do not stand alone. These explanatory elements are merged and enhanced by the usage of explanatory elements from the other clusters. Their impact also derives from this merger. One example is the effect of merging the narrative category of the story cluster with the positive analogy category as found in the astrophysics lecture. We classified an instance as a narrative if we could identify a narrator, who tells us about a protagonist involved in an event that happened in the past, and serves as main explanatory tool [16].

An important idea that was delivered in the astrophysics lecture was that star evolution is the underlying source of the diversity of atoms. The lecturer explained the evolution of stars through a positive analogy between the evolution of stars and the evolution of humans. This beautiful analogy was presented through a narrative about an alien that comes to earth, looks at the people, and tries to figure out how to describe them to his master (quoting from the lecture [17]): *"'I have come to earth and I have seen 125 people all different'. He [the alien] is smart enough to understand that the younger guy is the same as the older guy. In time, the little guy will get older and become like the older guy. It might not be the same object, the same person, but they evolve. This is an evolution. The same is true for stars: When we look at the sky we see different types of stars. We can recognize that some of them are young, and some of them are older, even if they are not the same objects. Just as you [audience] are not the same human beings".* We characterize this narrative as having an explanatory agent attribute because it 'carried' the analogy stars ~ humans. It created a 'time for telling' [18] which enhanced the impact of the analogy.

CONCLUSIONS AND IMPLICATIONS

Conceptual blending is one of the four clusters of categories from which TSEs, Translated Scientific Explanation, in popular physics lectures are derived. The other three are Story, Content, and Knowledge organization. These clusters were found in all three lectures. The explanatory framework may suggest *how* the lecturer can fit the content of the presentation to his/her audience's prior knowledge when formal prior knowledge is lacking. This process was demonstrated in this paper through the use of the conceptual blending cluster, but it should be noted that all the other clusters take part in this process. A full description of the 'Translated Scientific Explanation' (TSE) explanatory framework is in preparation.

Differences among lectures emerge when the categories that make up each cluster are examined. The explanatory framework can be used to create a lecture profile. Such profiles could be used as a methodological design tool to guide the utilization of popular physics lectures to teach contemporary physics to learners who lack a sufficient academic science background (high school physics students for example). The lectures can be used as an instructional source, where their profiles suggest possible mediation tools.

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