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# Augmented lectures: benefits of supporting physics teaching with the theatre

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**Abstract.** Young generations are less and less interested in studying STEM subjects. For this reason, numerous studies have strongly suggested a change in the methods scientific knowledge is developed in the learners, through the use of alternative and more creative strategies. In recent decades a strong interaction between scientific subjects and the arts has been established by means of theatre. The objective is to bring science to students and the public in ways that are engaging, instructive, artistic and, always, content-driven: the medium is the arts; the message is the joy of science. When we talk about Physics in a theatre show, are we only making a good dissemination or are we also transmitting contents and changing the nature of science view of the audience? In order to address this question, after the augmented lecture titled “There are no things inside things”, we invited the audience to answer both to a closed-answer survey about the performance and to an open-ended questionnaire focused on the theme “what is understanding?”, in terms of physics contents and NoS view. In this contribution, we analyze and discuss the answers provided by the people who have attended the augmented lecture. The analysis of the answers shows that the performance was appreciated as an example of showmanship in facing the wide-range cultural message of physics.

## 1. Introduction

For a mature citizenship, the importance of science education both in and out of schools, as well as in higher education, has been recognized worldwide. The European Union (EU) has recently put in evidence how Theatre and Showmanship can be a way for approaching Inquiry-Based Science Education (IBSE) and implementing it in the classroom, for instance through the EU project TEMI (Teaching Enquiry with Mysteries Incorporated). IBSE is well acknowledged in Science Education Research as a natural framework in which the learners can find opportunities for learning scientific concepts in terms of an active construction of meaningful knowledge [1] in both informal and formal pedagogical situations. However, the bidirectional links between informal and formal science education need further research with respect to their nature and effects.

In recent decades a strong interaction between scientific subjects and the arts has been established by means of theatre, for example at the City University of New York [2] or thanks to the Fusion Science Theater, a cross-disciplinary organization, funded by the National Science Foundation, dedicated to using theater to engage the audience in learning science concepts [3]. In Italy, the group “Lo Spettacolo della Fisica” (The Physics Show), founded by M. Carpineti, M. Giliberti and N. Ludwig of the University of Milan, has been making research about how to make scientific theatre a powerful tool in physics education, since 2004 [4-6]. From the beginning, its strategy has always been to write and



perform real theatre shows, staging scientific experiments with reflections on the role and on the meaning of physics and of research. In 2017, “Lo Spettacolo della Fisica”, together with Stefano Oss of the University of Trento and Andrea Brunello of the Portland Theatre (Trento, Italy) created and developed the idea of performing “Augmented lectures”. These are lectures to be performed in a theatrical setting with the help of professional actors (and or of painters, musicians, cooks, etc.) with the aim to make people think and reflect on some specific disciplinary topic and getting involved. They can be seen as complementary lectures that can also be part of a secondary school, or even of a university, formal path in physics instruction. “Lo Spettacolo della Fisica” wrote and performed 7 plays with 380 replicas, reaching about 130.000 people and 3 “augmented lectures”.

## 2. Physics at Theatre

The outcomes of most international research projects [7] highlight that, in order to promote authentic learning, teaching strategies should be model-oriented, allowing the physics-specific viewpoints on the world to emerge gradually. In doing this, teaching should compare the complexity of facts with the complexity of concepts. What is often necessary to motivate understanding is, therefore, a profound restructuring of the physics knowledge mediated by textbooks with the help of a synergic addition of meta-reflections on the physics itself. As is well known, learning and motivation to study start from the real world a student lives in and is closely related to it. In fact, student’s knowledge results from the interaction with the social, affective and phenomenological reality, that are at the foundations of a suitable scientific literacy [8-10]. Being the environment a student lives in so important, it is fundamental to outline not only in schools but also in the extra scholastic world, an image of physics that is full of charm and potentiality. It is therefore evident that a more incisive teaching/learning approach requires both, new professional skills (together with more sophisticated didactical strategies) of the teachers and a deeper diffusion of physics into society. Theatre works in both directions: it is an aid to develop professional skills (for example dialogue, unusual perspectives and showmanship [11,12]) and can be present as a part of an educated open society.

When we talk about Physics in a theater show, we have in mind a large set of very different experiences which correspond to different shades in the relation between science and theatre and that mainly depend on the audience to be addressed, and the message and the image of science to be conveyed. From such a background, some questions immediately emerge.

a) How and to what extent can science and theatre merge, giving up something of their own, but giving rise to a reasonable and stimulating communication?

b) Should science theatre, mostly the one addressed to students, primarily rely on emotions or on concepts?

c) In writing, preparing and performing a science show, are we only making a good dissemination or are we also transmitting contents and changing the Nature of Science (NoS) view of the audience [4]?

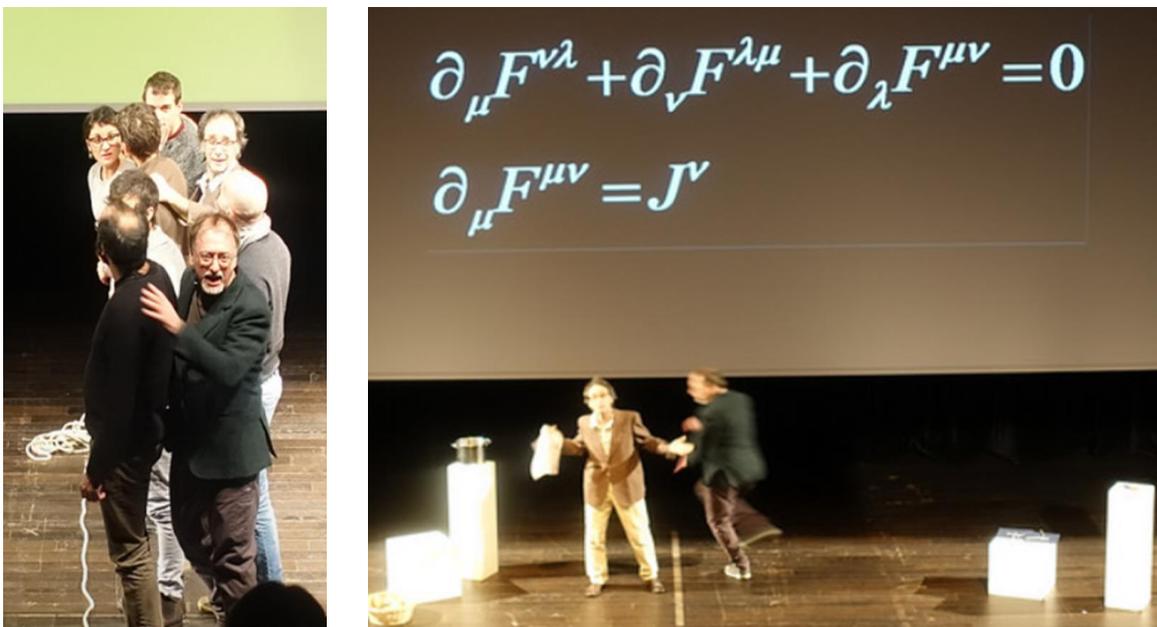
Concerning this point, let us stress that a survey on the perception of physics, carried out with a sample of approximately one thousand high school students in the province of Milan [13, 14], showed that while most of them believe Physics does provide an important contribution to society, they also consider it does not give important contributions to the ways of thinking in general! A task generally thought to be a prerogative of humanistic subjects.

The answers to the questions above are closely related to the goals and the framework one has focused on. In this contribution we address to question c) in a given context: the Augmented Lecture titled “There are no things inside things”, performed by one of the authors (MG) together with a professional actor at the University of Palermo (Italy) in May 2017. After the show, we invited the audience to answer both to a closed-answer survey about the performance and an open-ended questionnaire focused on the theme “what is understanding?”, in terms of physics contents and NoS view. We here analyze and discuss the answers provided by the people who have attended the augmented lecture.

### 2.1. The Augmented Lecture “THERE ARE NO THINGS INSIDE THINGS”

Duration: 70 m – From 16 years old people – Location: Palermo (Italy) - Audience: about 500 People (for a somewhat deeper description of the play see for instance [15]).

A physicist (M. Giliberti) and an actor (Giacomo Anderle) act together discussing real data experiments, singing songs while dancing, commenting on equations and involving the audience on stage. The show is focused on the double slit experiment performed in different settings: from the well-known experiments with photons and electrons, up to those with atoms, fullerenes, and tetraphenylporphyrin. It also presents and discusses some crucial aspects of Quantum Mechanics. At the basis of quantum mechanics, there is elegance and simplicity: it is precisely this simplicity, clearly related to its explicative power, that upsets us because, on the contrary, the world we are used to is complicated. Some of the peculiarities of Quantum Physics are therefore a stimulus to understand the meaning of explaining, in physical sciences.



**Figure 1.** Snapshots of the show “THERE ARE NO THINGS INSIDE THINGS”, with audience involvement.

## 2.2. The questionnaire

At the end of the show, we invited the audience to answer to both a closed-answer survey about the level of engagement/satisfaction and an open-ended questionnaire focused on the theme “what is understanding?”. The entire questionnaire is shown in the Appendix.

Our analysis of the answers is differentiated for the level of student previous knowledge, by distinguishing among those instructed about the topic of the show (undergraduates or students at the last year of secondary school) and students who never studied the physics contents introduced within the augmented lecture. In particular,

- Group 1 (n=15) is a sample of students attending the second year of the Vocational School for Optometrist Optician “Fermi-Eredia” in Catania;
- Group 2 (n=50) collects students from the third or fourth year of Scientific Lyceum “B. Croce” in Palermo;
- Group 3 (n=151) is formed by students of the last year of the Scientific High-Schools of Palermo and province;

- the undergraduates of the first year of the Mechanical Engineering Course of the University of Palermo belong to Group 4 (n=16);
- finally, the teachers belong to Group 5 (n=9).

In this contribution, we discuss the student/teacher affective development and motivation to learn/teach, by means of the analysis of the answers to the closed-answer questionnaire having specific items related to the interest/enjoyment dimension and to the perceived competence dimension. A robust quantitative analysis of the answers provided by the audience to the open-ended questionnaire, focused on the theme “what is understanding?”, will be the subject of a forthcoming paper. Here, we report a preliminary analysis of the answers, which shows very interesting results. In order to quantify the student/teacher satisfaction we used a five-point Likert scale: 5: Strongly agree; 4: Agree; 3: Neither agree nor disagree; 2: Disagree; 1: Strongly disagree.

Table 1 shows the mean and the standard deviation of student and teacher outcomes for the five following questions: “Do you think that the augmented lecture...”

- 1) represents an innovative Science communication experiment?
- 2) adds an emotional dimension to the scientific content, stimulating curiosity?
- 3) thrills to the study of Physics?
- 4) effectively presents experiments that highlight the peculiarities of Quantum Mechanics?
- 5) explains why Quantum Physics is considered to be difficult?

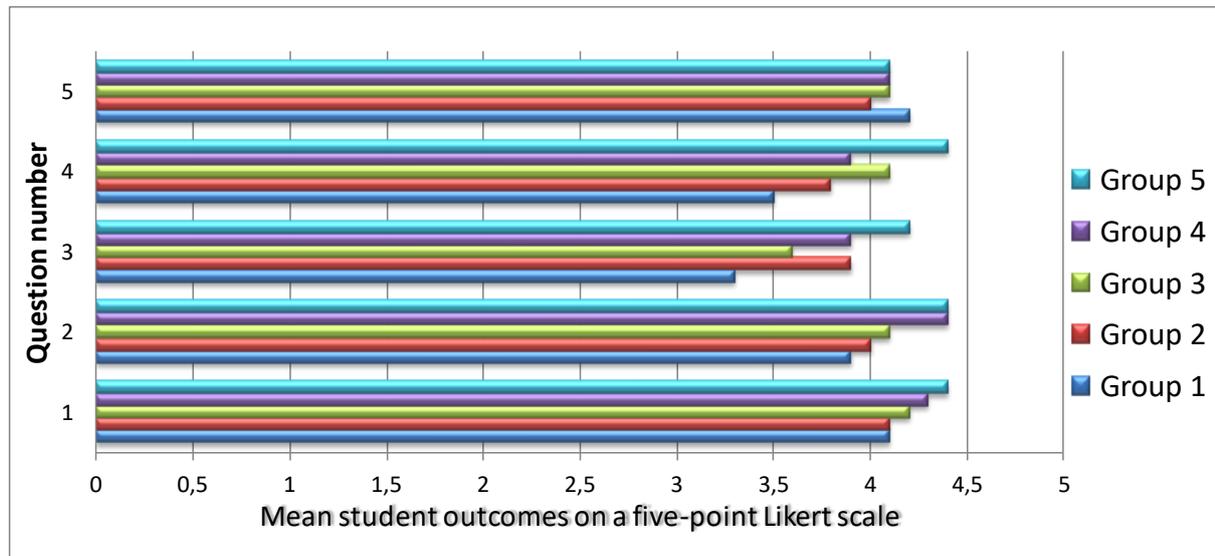
**Table 1.** Mean and standard deviation of student/teacher outcomes on a five-point Likert scale.

Question number	Group 1	Group 2	Group 3	Group 4	Group 5
1	4,1±0,8	4,1±0,7	4,2± 0,7	4,3±0,4	4,4±0,7
2	3,9±0,9	4,0±0,6	4,1± 0,7	4,4±0,7	4,4±0,7
3	3,3±1,1	3,9±0,6	3,6± 0,9	3,9±0,6	4,2±0,6
4	3,5±0,6	3,8±0,7	4,1± 0,8	3,9±0,6	4,4±0,7
5	4,2±0,7	4,0±0,7	4,1± 0,8	4,1±0,8	4,1±0,6

### 3. Results and Discussion

As shown in Figure 2, all the questions, on average, received high marks and, in particular, question number 1 registered the highest average evaluation, confirming a global satisfaction of the audience for this innovative way of science communication. However, we have also to point out that about 25% of people attending the Augmented Lecture did not fill out the questionnaire at the end of the performance. Even more relevant, among these about 45% of the teachers. Question number 3: “Do you think that the augmented lecture thrills to the study of Physics?” got the lowest mean scores. This is precisely the results expected for a performance studied to be a connection between a formal in-class teaching and an informal theatre show. While still perceived as enjoyable, the lecture is seen more as a way of lecturing in a different effective way than as a theatre performance (the setting, Aula Magna of the Polytechnic School of the Palermo University, instead of a theatre, might also have guided this judgment).

In Figure 3, we show the percentage outcomes on a five-point Likert scale to the five questions for the different groups, in order to give more details on the collected feedback and also to compare the findings with respect to the different age and educational background of participants.



**Figure 2.** Mean student outcomes on a five-point Likert scale to the five questions.

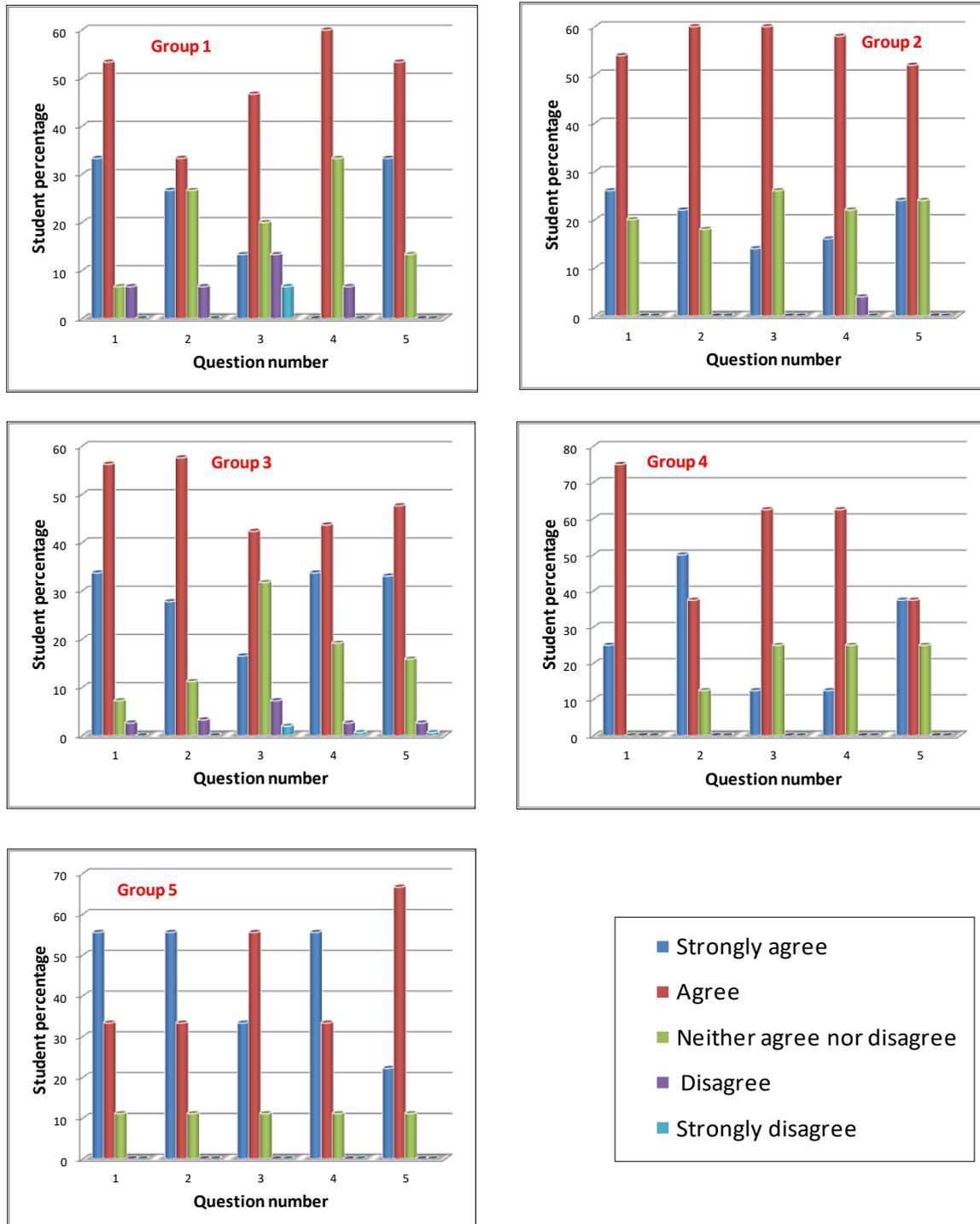
In particular, the people belonging to Group 1 ( $n=15$ ) are 15-16 years old - the youngest in this survey - and are the only students attending a vocational school. They registered the lowest average evaluation on the five questions, showing large indecision about question number 2 (Do you think that the augmented lecture adds an emotional dimension to the scientific content, stimulating curiosity?) and question number 3 (Do you think that the augmented lecture thrills to the study of Physics?). Moreover, none of the students is strongly in accordance with the statement that the augmented lecture effectively presents experiments that highlight the peculiarities of Quantum Mechanics. This can be ascribed to the fact of being second-year vocational school students. They have just started to study Quantum Mechanics in a qualitative way and because of it probably they were not able to reflect enough on QM peculiarities and implications.

Group 2 ( $n=50$ ) collects students from the third or fourth year of the Scientific Lyceum “B. Croce” in Palermo. They are 16-17 years old and never studied Modern Physics. In this case, the sample feedback appears to be very homogeneous in all the five questions. More than 50% of students is globally satisfied with this innovative way to do science communication.

Group 3 ( $n=151$ ) is the most numerous and it is formed by students of 18-19 years old attending the last year of Scientific High-Schools of Palermo and province, who have already studied Modern Physics. Similarly to the outcomes from Group 1, the students belonging to Group 3 are undecided and a significant fraction of students is unsatisfied with the performance. In this case, the greater broadening is registered for the question 3 (Do you think that the augmented lecture thrills to the study of Physics?), but lower percentages of agreement are registered also for questions 4 (Do you think that the augmented lecture effectively presents experiments that highlight the peculiarities of Quantum Mechanics?) and 5 (Do you think that the augmented lecture explains why Quantum Physics is considered to be difficult?). This result is difficult to understand, but at a first sight, it seems as the students detected a sort of split among the topics of Quantum Mechanics studied at school and the contents of the augmented lecture.

Group 4 ( $n=16$ ) registered a high average evaluation in all the questions. Undergraduates of the first year of the Bachelor in Mechanical Engineering of the University of Palermo belong to Group 4 (age 18-20 years). They already studied Modern Physics at the high school and attended the Courses of Mechanics and Electromagnetism at University. During the augmented lecture, they appeared very excited for the topic and many of them asked interesting questions to the actors at the end of the performance. Nevertheless, about 20% appears undecided on the last 3 questions.

The teachers (n=9) who compiled the survey (Group 5) were very satisfied with this new exemplum of science communication.



**Figure 3.** Student percentage outcomes on a five-point Likert scale to the five questions for the different groups.

#### 4. Conclusion

Recent studies report an alarming decline of interest of young generations in studying scientific topics. Because of this, a change in the methods scientific knowledge is developed in the learners, through the use of alternative and more creative strategies is strongly suggested. An interaction between STEM subjects and the arts has been established by means of theatre with the objective of bringing science to students and the wide audience in ways that are engaging, instructive, and artistic, but always, content-driven.

In this contribution we focused on the question of whether in writing, preparing and performing a science show, are we only making a good dissemination or are we also transmitting contents and changing the nature of science view of the audience, in a given context (the Augmented Lecture titled "There are no things inside things" - performed at the University of Palermo (Italy) in May 2017. In particular, here we have analyzed and discussed on a Likert scale the closed answers provided by the people who have attended the augmented lecture. All the questions, on average, received high scores confirming a global satisfaction of the audience for this innovative way of doing science communication. The performance was appreciated as an example of showmanship in facing the wide-range cultural message of physics. The collected feedback was also analyzed with respect to the different age and educational background of participants. A preliminary analysis of the answers to the open-ended questions on the theme "what is understanding?" shows very interesting results that will be the subject of a forthcoming study.

#### Acknowledgments

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#### Appendix

##### Questionnaire

A. Do you think that the augmented lecture "THERE ARE NO THINGS INSIDE THINGS":

		Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
1	represents an innovative Science communication experiment?					
2	adds an emotional dimension to the scientific content, stimulating curiosity?					
3	thrills to the study of Physics?					
4	effectively presents experiments that highlight the peculiarities of Quantum Mechanics?					
5	explains why Quantum Physics is considered to be difficult?					

B. In your opinion what does it mean "understanding"?

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C. What did the double slit experiment teach you??

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D. Is Quantum Mechanics simple or complicated? Motivate your answer.

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