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The Use of Drama in Science Education: The Case of "Blegdamsvej Faust"

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ABSTRACT. This is a study of the structure of 'The Blegdamsvej Faust' and its relation to Goethe's classical play Faust. The 'Blegdamsvej Faust', a play written and performed by Bohr's students in 1932, is inspired by the very rapid development of Physics in those turbulent years. A struggle is made to promote the odd idea of a weightless particle. Moreover, this study lays emphasis on the fact that new ideas of Physical Sciences become more accessible, comprehensible and familiar through dramatization. For scenario-vehicles one may use as a basis plays from the classical repertoire or write something new. Several hints are given in this article.

INTRODUCTION

The central point of this study is to promote a theatrical way by which the scientific knowledge can be presented. This version incorporates not only Physical Sciences and Pedagogy, but also the theatrical side of teaching in general. Besides, theater has been used for teaching since its birth.

A drama, which has been used with great success to present and clarify new ideas in Physics is the '*The Blegdamsvej Faust*'.[1] It was written by Bohr's students and performed by them at the symposium which took place in Bohr's Institute of Theoretical Physics in Copenhagen, in spring of 1932. This play was based on Goethe's classical drama Faust and Pauli corresponds to Mephistopheles – Satan, Ehrenfest to Faust, Bohr to God and Pauli's weightless neutron to Gretchen. Some years later, Pauli's neutron was named by Fermi *neutrino* in order to get over any confusion. The main idea of 'The Blegdamsvej Faust' starts from a bet between Pauli–Mephistopheles and Bohr–God. The first one insists that he can sell the idea of his neutron to Ehrenfest–Faust.

A BRIEF HISTORICAL REVIEW

The early decades of the present century witnessed the heady development of the Quantum Theory of the atom and during that era the roads of theoreticians of all nationalities led to Copenhagen, the home city of Niels Bohr, who was the first to formulate the correct atomic model. It became customary at the end of each spring conference at Blegdamsvej 15 to produce a stunt pertaining to recent developments in Physics. The 1932

conference, which coincided with the tenth anniversary of Bohr's Institute, followed closely on the British physicist James Chadwick's discovery of a new particle *having the same mass as a proton but deprived of any electric charge*. Chadwick called it the 'neutron'. But there was some mix-up in terminology. A few years earlier Wolfgang Pauli used the same name for a hypothetical particle which had no mass and no charge. Pauli postulated the existence of weightless neutron to solve the long-standing problem of the electron energy spectrum observed in β decay. Pauli's neutron was the subject of hot discussions among the physicists, but these discussions were exclusively oral or carried on by private correspondence, and the name was never 'copyrighted' through appearance in any publication. Thus, when the discovery of Chadwick's heavy neutron was announced in his 1932 paper in *Nature*, the name of Pauli's weightless neutron had to be changed. Enrico Fermi proposed calling it the *neutrino*, which in Italian means a little neutron. Many physicists, especially Paul Ehrenfest, of Lieden, were very skeptical concerning Pauli's hypothetical neutrino, and it was only in 1955 that its existence was indisputably proved by Fred Reimes and Cloyd Cowan's experiments of the Los Alamos Scientific Laboratory (Gamow 1966).

The discussion about neutrino is still open, as it is shown by the international conference, 'Neutrino 98', that took place in Takayama, Japan in June. The Super-Kamiokande collaboration, made up of 23 institutions from Japan and the US, announced evidence for non-zero neutrino mass. If confirmed, it will force a revision of the Standard Model, which up to now has been able to describe all available data on particles and forces (Lemaire 1998).

'FAUST' – 'THE BLEGDAMSVEJ FAUST': PARALLEL ROUTES

Abstract of Goethe's 'Faust'

The play begins with the dialogue between God and Mephistopheles. From this dialogue a bet is born, according to which Mephistopheles tries to tempt Faust – a man torn between heaven and earth.

Mephistopheles tries to put both Faust's mind and soul to the test and finally Faust accepts the challenge. According to their argument the day in which Faust will yield to worthless, insignificant and fleeting riches, will be the last day of his life.

Faust begins to wander being Mephistopheles's loyal attendant. Faust tastes incredible pleasures of the flesh, experiences Gretchen's pure and innocent love, lives in affluence, smells the scent of power and becomes King having 'Beautiful Helen' as queen by his side. But during his roaming, Faust has abandoned himself to Mephistopheles's tricks and devious games. He has given in to immeasurable shabby temptations and has

almost been identified with Mephistopheles, his charmer-mentor, in earthly pleasures.

However, when Faust is close to the end of his wandering, he realizes that by following Mephistopheles, he has not become a wiser person. He has not broadened either the field of his scientific knowledge or his philosophy. He isn't sure if his mind or his sense of logic worked on Mephistopheles's feelings even for a glimpse of time. The audience has also the same sensation. The readers-viewers of the play feel insecure about the winner and the loser of the primary bet. Even the profits of the victory are questionable. None of them, Mephistopheles or Faust, would be able to crow over his victory. In any case, doubt is responsible for the existence of science (Goethe[(a)]).

Abstract of 'The Blegdamsvej Faust'

The plot starts with the dialogue between Bohr and Pauli. Pauli, who is the adherent of the idea of weightless neutron – Pauli's neutron (neutrino) – bets Bohr on his own ability to transfer this idea to Ehrenfest who represents the scientific status quo.

As Pauli tries to convince Ehrenfest about his idea, he pretends a salesman who propose merchandise as Psi-Psi Star ($\Psi\Psi^*$), Electrodynamics etc. Finally Pauli shows Ehrenfest his neutron, personified as a woman, whose name is Gretchen. But Ehrenfest who is uncompromised from the beginning, doesn't accept Pauli's neutron and his behavior causes Gretchen's physical death.

Afterwards, Ehrenfest has the experience of two Walpurgis Nights. These nights are descended from the German folklore and are full of orgiastic events. He has the chance to wander through his science. During the first Walpurgis Night he agrees to neglect the Classical Theory while at the second one he pays attention to the subjects introduced by the Quantum Theory. After his meeting with the Quantum Theory he feels so pleased that he is ready to die because his reason of existence has been fulfilled.

At the end of the play the scientific society welcomes a new particle which was revealed during an experiment although no theory had predicted it. This new particle is Chadwick's neutron; the real neutron. Pauli participates in the general happiness for the new discovery, feeling extremely sure about his own particle – Neutrino – and looking forward to a further personal satisfaction through the experiment.

ELEMENTS OF THE SCENARIO

The elements of a scenario are (Kehagias 1997):

- The Idea
- The Source of Inspiration

- The Characters
- The Plot, The Conflict, The Final Denouement

The identification of the above elements in the case of '*The Blegdamsvej Faust*' is the following:

The Idea

The main idea of the play is the struggle of the new knowledge for its acceptance by the scientific community. It is the eternal struggle against the prejudices, which hamper progress rather than foster it (Heisenberg 1983).

The Source of Inspiration

'Goethe's Faust' has been chosen as the source of inspiration for the following reasons:

- Goethe's Faust – finally completed in 1831 – belongs to a wide period of literature and theatre, called '*Storm and Impulse*' ('S + I'). This period (second half of 17th century-first half of 18th century) was a literary evolution aiming to refresh the whole art. The authors of 'S + I' are intellectuals-moralists and vehicles of important ideas (Markaris 1996; Ferguson 1949). 'The Blegdamsvej Faust' was probably written in 1930 and has the characteristics of 'S + I' period because its target is to reveal the rebellious face of science during the first decades of our century. The characters of the play are various scientists of that period as Bohr, Pauli, Ehrenfest, Dirac, Gamow etc.
- The science itself is identical to Faust's character, meaning that there is a continuous struggle between the old and the new. Faust's suspense reflects the hidden face of the science. Goethe (1749–1832) had studied physics and was the first one who had the opinion that science looks like Faust, that is, there is a struggle between the bad and the good embodied in the scientific ideas with the intention to capture the human soul (Goethe[(b)]).

The Characters

The main characters of the play are:

- Ehrenfest – Faust

He has two different faces. He is a teacher who always criticizes the scientific knowledge and at the same time he is a student – an unexpelled characteristic – when he meets the Quantum Theory, during the second Walpurgis Night of Quantum Theory. Ehrenfest wonders about his Knowledge:

... ...I have – alas – learned Valence Chemistry,
Theory of Groups, of the Electric Field,
And Transformation Theory as revealed
By Sophus Lie in eighteen – ninety – three.

Yet here I stand, for all my lore,
No wiser than I was before.
M.A. I'm called, and Doctor. Up and down,
Round and about, the pupils have been guided
By this poor errin' Faust and witless clown;
They break their heads on Physics, just as I did.
But still I'm better than the cranks,
The Big Shots, monkeys, mountebanks.
All doubts assail me; so does every scruple;
And Pauli as the Devil himself I fear.
I grab the eraser, like a frantic pupil,
Before the magic X-ings[3] *disappear,*
For what is written down on black, in white,
Is apt to be acceptable and right... ... .

• Pauli–Mephistopheles
As Mephistopheles, he is the bad character of the play. He is the man who uses tricks in order to evoke his idea. The audience, watching Pauli's development during the play, faces a teacher who fails in passing through the brand-new knowledge, the new notion, to his student Ehrenfest (Pantidos 1997).
• Pauli's Neutron – Gretchen – Neutrino
She personifies the new knowledge. When Gretchen appears to Ehrenfest for the first time, she says:

... ...NEUTRINO – GRETCHEN

My mass is zero,
My Charge is the same.
You are my hero,
Neutrino's my name.

I am your fate,
And I'm your key.
Closed is the gate
For lack of me.

Beta-rays[6] *throng*
With me to pair
The N-spins[7] *wrong*
If I'm not there.

My Mass is zero,
My Charge is the same.
You are my hero,
Neutrino's my name

My psyche turns
To you, my own.
My poor heart yearns
For you alone

My lovesick soul
Is yours to win.
I can't control
My trembling spin.

My Mass is zero,
My Charge is the same.
You are my hero,
Neutrino's my name

By this impersonation, Scientific Knowledge thinks, acts and gets involved with the other characters.

Some other physical notions, constants and variables, such as *Gauge*

Invariant, *Fine Structure Constant*, *Negative Energy*, *Singularity*, have turned out to be human beings in order to emphasize the importance of the main idea of the play. Their appearance is marked by a vital dialogue which follows:

... ... (Dirac comes forward, followed by four gray women)
THE FIRST
The Gauge Invariant is my name.

THE SECOND
I'm of Fine Structure Constant^2 *fame.*

THE THIRD
Negative Energy – That's me.

THE FOURTH
(to the third)
Just watch your grammar, Number Three!
(to the others)
Sisters, into the reckoning
You cannot and you may not spring.
But in the end there I shall be,
For I am Singularity!
(The four stand to the side of the stage, to mingle in later and Faust comes in) ... .

The Plot, The Conflict, The Final Denouement

- *The main idea of the play is being helped by smaller stories which function as propulsive ones.*

From this point of view, Pauli accompanied by Ehrenfest go to Ann Arbor's bar,[4] where they meet some patrons who are American physicists and are sitting sad and disappointed with the deadlock that Physics has come to. They find comfort in drinking and they pity themselves. Basically, Pauli wants to prove that within the infertility and disillusion that Physics has been trapped, he is the only one who has something really important to say. So, being Pauli in Ann Arbor's bar, he introduces his neutron – Gretchen:

... ... PAULI–MEPHISTO
(springing forward behind the bar)
Can no one laugh? Will no one drink?
I'll teach you Physics in a wink ...
(he winks exaggerately and knowingly at the physicists)
Shame on you, sitting in a daze
When as a rule you're all blaze!

OPPIE[5]
(swallowing – Njum! Njum! – before speaking)

Your fault! You've brought no single word of cheer-
No news, no X-ings. Bah!

PAULI–MEPHISTO
(producing Gretchen – Neutrino)
But both are here! ... .

Unfortunately, as luck would have it, Pauli leads Ehrenfest to a totally different upshot. Ehrenfest disgusts all this chaos and racket about him in this bar and repudiates Pauli's idea once and for all:

... ... EHRENFEST–FAUST
(to Mephisto)
Do you expect me to get well
In all this chaos, din and hell?
(to Gretchen)
You Skeleton, you Monster, here I stand,
But do you recognize your lord and master?
What holds me back? See here, I take your hand
And shatter you!

NEUTRINO–GRETCHEN
Faust, Faust, I fear disaster! ... .

Exactly at this point, we have a *reversal of the plot*. Although the aim of the main story is Ehrenfest to be convinced by Pauli, due to the intervention of this smaller story, we have the opposite outcome. The *following two other shorter stories*, complete and extent one another. These are the two Walpurgis Nights. One of the Classical Theory and one of the Quantum Theory. During the Classical Walpurgis Night, Pauli being affected by its atmosphere, ventured to express his will to depart from Classical Theory:

... ... EHRENFEST–FAUST
Why not skip this, and go to Quantum Theory?

DELBRUCK – MASTER OF CEREMONIES (M.C.)
If we do that, I fail as an M.C.,
For first the Classical must duly close.

EHRENFEST–FAUST
I have two different time-scales to propose
For these Walpurgis Nights. As I've avowed,
The First should go to limbo.

DIRAC
Not allowed!

EHRENFEST–FAUST
I then propose the Classical be moved
Much farther back in time and place.

M.C.
Approved! ... ...

The second Walpurgis Night of the Quantum Theory and its happenings, bring Ehrenfest to a situation of ecstasy and admiration about his science. This situation makes him feel as the perfect scientist and he wishes to die in order to save for ever the happiest moment of his life.

- *In order to create a conflict among the characters, obstacles are put which cause debates and disagreements.*

The most important obstacle for Ehrenfest, which doesn't let him accept the idea of neutrino, is his own attitude in life which is opposite to Pauli's one. In other words they differ in the way they realize the philosophy of science.

Attention must be paid to an important element which comes out from obstacles in writing such a scenario. A scenario based on Physics, has the possibility to use many important obstacles because Physics is expressed through Mathematics. *So, a limitation in Mathematics, functions as an obstacle in a scenario.*

- *The evolution of the play reaches a peak at the moment of Ehrenfest's death.*

As mentioned above Ehrenfest has rejected Pauli's neutron. Ehrenfest's death comes as a normal consequence for the audience, following the evolution of the action. Ehrenfest, as he has been presented, claims that he has learned a lot about Physics but at the same time suffers because he feels that nothing important was proposed by himself. However, his participation in Walpurgis Night of Quantum Theory, gave him a relief and happiness, an outlet to his grief:

... ... EHRENFEST - FAUST
To this fair moment let me say:
You are so beautiful - Oh, stay!
A trace of me will linger 'mongst the Great,
Within the annals of The Fourth Estate.
Anticipating fortune so begin,
I now enjoy the moment that is mine!
(He dies, and his body is carried out) ... ...

His death signs the end of the play.

- *After Ehrenfest's death the play comes to an end welcoming the Chadwick's real neutron.*

The announcement about the existence of the neutron belongs to Chadwick and took place at the same symposium during which this play was performed.

Eventually, the struggle between the old and the new knowledge brings to light something brand-new. A singular thing, a breakthrough happened: the discovery of Chadwick's neutron – the real neutron, although the

main idea of the play was 'Pauli's neutron' – neutrino. This obliges Pauli to say:

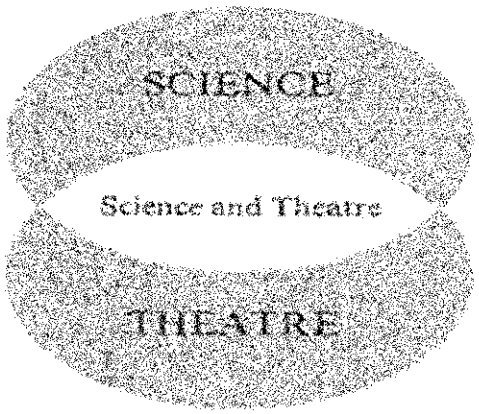
... ... That which experiment has found –
Though theory had no part in –
Is always reckoned more than sound
To put your mind and heart in.
Good luck, you heavyweight Ersatz[8] *–*
We welcome you with pleasure!
But passion ever spins our plots,
And Gretchen is my treasure! ... .

Neutron, establishes the existence of electrically neutral elementary particles. In other words the controversial idea of neutrino, with zero mass and zero load, was half-reached. The end of the play is open for there is no end in Physics too. The play ends with a Choral song:

... ... Now a reality,
Once but a vision.
What classicality,
Grace and precision!
Hailed with cordiality,
Honored in song,
Eternal Neutrality
Pulls us along!

CONCLUSIONS

- Dramatizing a scientific subject, its message can be commented and presented in a different atmosphere, which has a special dynamics and creates more favorable conditions for its approach.
- It is possible to have theatrical plays based on subjects of Physics, either based on scenarios from the classical repertoire, or based on totally new plays written nowadays (http://www.pa.msu.edu/sci_theatre/). We are talking about scenarios which belong to the category of '*Science and Theatre*'. One vital element of this category is the impersonation of physical notions or physical quantities.



- On a small scale, theatrical elements may be useful during hourly lessons provided that teacher has the proper theatrical education and knows how to organize his lectures. (Pantidos et al. 1996; Taylor 1988).

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NOTES

[1] Blegdamsvej 15. The then address of Bohr's Institute of Theoretical Physics.
[2] Fine Structure Constant, the number 1/137, which is important in the theory of the atom.
[3] X-ings ('Ixerei' in German) is a word invented by Einstein and was often used about papers which contained too much complicated mathematics ('X' is the unknown in school algebra), but little physical content.
[4] Referring to the University of Michigan at Ann Arbor, Michigan.
[5] R. Oppenheimer, American physicist.
[6] Beta-rays. According to Pauli's hypothesis, the neutrino is a particle which always accompanies the emission of a Beta-ray from the nucleus.
[7] N-spin. According to the views of those days, the spin (axial rotation) of the nitrogen nucleus could not be explained without considering the spin of the hypothetical neutrino.
[8] Ersatz. The neutron, with its large mass, cannot be considered as a substitute ('Ersatz') for the weightless neutrino.

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