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ALI CLIL
PROGETTO LINGUE LOMBARDIA

A Disappearing Number

A Teacher's Guide

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TEATRO SCIENZA 2008

Foreword

These materials are produced by the Ministry of Education, University and Research – Regional Education Authority for Lombardy – Multilingualism and Internationalisation Area in collaboration with Teatro Scienza 2008.

T to the S. Theatre to the power of Science. Or more simply, Science Theatre, an event dedicated to contemporary experiences investigating the relationship between the stage and scientific culture. The purpose is to get young people curious, and thus to get them passionate about scientific studies, through drama. The project involves schools directly, from primary to university level, with performance-lessons, training workshops, meetings for students and teachers, theatrical performances and a portal dedicated to the exchange of ideas, including a great on-line competition to become “Actors of Knowledge”. From October 2008 to May 2009 there will be many different occasions to get to know the magical world of science and discover how it can be expressed through theatre.
The initiative involves the cooperation of prestigious Milanese institutions such as the Silvio Tronchetti Provera Foundation, the Umberto Veronesi Foundation for Scientific Progress, the Piccolo Theatre of Milan – Theatre of Europe, Milan Polytechnic, Milan State University, Milan Bicocca University and Science Under 18.

At present this Guide is aimed chiefly at teachers, who can choose what to use and when, and how to integrate this material with the three distinct theatrical moments: the lesson in class by the theatre expert in October 2008, the performance lesson at Strehler Theatre, and the final performance in November 2008.

The dossier consists of the following elements:

1. A short biography of Srinivasa Ramanujan
2. Characters featured in the play
3. Summary of the action occurring on stage
4. Background notes:
   - 4.1 A short outline
   - 4.2 Features of the play
   - 4.3 Ramanujan and Cambridge
   - 4.4 Ramanujan's Mathematics
   - 4.5 Basic mathematical concepts
5. Teaching/learning activities

The material is available online at http://www.progettolingue.net.
We hope you find these materials useful; please do not hesitate to contact the team if you need further information at lingue@istruzione.lombardia.it.

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Milan, October 10, 2008

1. A SHORT BIOGRAPHY OF SRINIVASA RAMANUJAN

Srinivasa Ramanujan was one of the most outstanding figures in the mathematical field during the early 20th century. Unluckily he had a very difficult life and went through a long series of hardships before entering into the golden world of Cambridge academic life.

He was born in Erode, a small village 400 km far from Madras and in 1887 at the age of one he was taken to Kumbakonam where his father worked.
As soon as he entered the Town High School at the age of 11, he distinguished himself as a very bright all-round student with exceptional gifts in mathematics, although he was essentially self-taught.

In 1904 he was given a scholarship to attend Government College in Kumbakonam. Unfortunately he lost the scholarship the following year as he had only concentrated on maths neglecting all the other subjects. This trend continued in 1906 when he moved to Madras and tried to enter University but, although extraordinarily gifted in maths, he failed in all the other subjects, yet he continued working on his own original ideas from 1907 to 1911.
Despite his failure in proceeding with his university education, he acquired a high standing in his field after the publication of a brilliant research paper on Bernoulli numbers in *The Journal of the Indian Mathematical Society*. Ramachadra Rao, secretary of the Indian Mathematical society, helped him earn a living during those tough years; thus he got a temporary job as a clerk at the Accountant's General Office in Madras and then was employed as a clerk at Madras Port Trust.
As a result of a pre-arranged marriage, he married a ten-year-old girl in 1909, S. Janaki Ammal, but did not start to live with her until 1912. Ramachadra Rao describes him as follows: "A short uncouth figure, stout, unshaven, not even clean, with one conspicuous feature, shining eyes, walked in with a notebook under his arm. He was miserably poor".

Thanks to people with a sound training in maths working around him, his talent was recognised and his paper on Bernoulli numbers was sent to M. J. Hill professor of maths at University College London. Hill replied politely but failed to understand Ramanujan's results on divergent series. Then Ramanujan wrote to other University professors, including G. H. Hardy, Professor at Trinity College, Cambridge, who eventually showed a keen interest on his studies as observed in a letter dated 8th February 1913:

"Your results seem to me to fall roughly into three categories:

1. *there are a number of results that are already known, or easily deducible from known theorems;*
2. *there are results that so far as I know, are new and interesting, but interesting rather from their curiosity and apparent difficulty than their importance;*
3. *there are results which appear to be new and important".*

Ramanujan enthusiastically replied that he had found a friend in him and asked first for some food as he was on the verge of starvation and then for a scholarship to go on with his studies.

The University of Madras granted him a two-year scholarship; in 1914 Hardy convinced Ramanujan, an orthodox Brahmin, to move to Cambridge Trinity College to begin a highly fruitful collaboration which the British mathematician was later to describe as the most romantic episode in his own life.
Ramanujan's mother objected to his voyage to England since this choice would have led him to lose his caste, but she eventually gave in.

Once in England Ramanujan had to face many difficulties: he had to get accustomed to English weather considering he came from a tropical climate, moreover he had to do his own cooking to adhere to his caste's strict vegetarian rules. Since some food items were hard to get in England in the period of World War 1, Ramanujan soon started to have problems with his eating habits.

Hardy took care of Ramanujan's lack of formal education and asked a friend and a collaborator, J. E. Littlewood, to mentor him to make him acquire rigorous mathematical methods. But Littlewood often felt at a loss with him because "*every time some matter, which he held Ramanujan should know, was mentioned Ramanujan's response was an avalanche of original ideas*" which invariably forced the former to change his original teaching plans.

Though unable to provide proper qualifications, Ramanujan was admitted to Cambridge University in 1914 where he obtained a degree on the basis of his original research. His dissertation dealt with highly composite numbers and included seven of his papers published in England.

In 1917 he was taken to hospital and doctors feared he would die of tuberculosis.
Hardy wrote "*like all Indians he is fatalistic, and it is terribly hard to get him to take care of himself*".
Ramanujan 's genius received worldwide recognition in 1918 when he was appointed a Fellow of the Cambridge Philosophical Society in February, then in May he became a member of the Royal Society and finally in October was elected a Fellow of Trinity College Cambridge.

Such honours proved to be beneficial to his health and Ramanujan was soon able to leave England for India in February 1919, where he died an untimely death the following year, due to a parasitic infection caught in India but not diagnosed in time in England.

Ramanujan left a number of unpublished notebooks filled with theorems that mathematicians have continued to study. G. N. Watson has published 30 papers which were inspired by Ramanujan's work.

In time a number of initiatives have flourished to commemorate both the man and his achievements:

- Ramanujan's home state of Tamil Nadu has chosen Ramanujan's birthday, 22nd December, as 'State IT Day'
- a stamp was issued in 1962 by the Indian Post Office to celebrate the 75th anniversary of his birth in 1962
- in 1997 the *Ramanujan Journal* was launched to publish work concerning areas of mathematics influenced by Ramanujan
- during the year 1987 (Ramanujan's centennial), the printed form of *Ramanujan's Lost Notebook* by the Narosa publishing house of Springer-Verlag was released by the late Indian prime minister Rajiv Gandhi, who presented the first copy to S. Janaki Ammal Ramanujan (Ramanujan's late widow) and the second copy to George Andrews in recognition of his contributions in the field of number theory.

Last but not least Ramanujan's towering figure has inspired several plays and films:

- the character Amita Ramanujan in the TV series *Numb3rs* was named after him
- *First Class Man* and *A Disappearing Number*, respectively directed by David Freeman and Simon McBurney, are two plays on the life of the Indian mathematician
- two films are at the moment being shot.

2. CHARACTERS FEATURED IN THE PLAY

Main characters

ANINDA	The narrator, an eye-witness, himself an Indian mathematician and lecturer, who leads Al through his journey to India.
AL COOPER	A dealer of Indian descent, married to Ruth
RUTH	University researcher and maths lecturer with an obsession with Indian genius Ramanujan. Married to Al.
SRINIVASA RAMANUJAN	Indian Maths Genius of Brahmin religion around whose life pivots most of the play. Married to Janaki Ammal.
HARDY	British don at Cambridge Trinity College, who discovered, supported and collaborated with Ramanujan until the latter's untimely death. He was fond of cricket and tennis, besides maths.

Minor characters

JANAKI	Ramanujan's wife
GERTRUDE	Hardy's sister
BARBARA	Operator in the Call Centre
SURITA	Brahmin woman on the train with Ruth; cleaner in Al's hotel room
DAVID	Al's friend
CLEANER IN LECTURE HALL	

Voices

BBC	
HARVARD PROFESSOR	
PLANE CAPTAIN	
SHANE	Lady in Madras' library
HOTEL INTRO	
CAMBRIDGE INFO	
VICTORIA	
ENGLISH VOICES FROM CAMBRIDGE	
INDIAN VOICE ON MEDITATION	
JACKSON	describes Cambridge during the war

3. SUMMARY OF THE ACTION OCCURRING ON STAGE

The following summary is intended as a guide for teachers. ***Be careful not to anticipate important theatrical surprises*** *when describing key events of the plot.*

NO.	TITLE and SETTING	SCENE SUMMARY
1.	**Opening Lecture** *Ruth, Aninda, Al, Hardy* Lecture Hall, theatre, Madras	**Ruth** scribbles series of numbers and feels the need to grasp hidden patterns. Besides stating that everything on stage is fictitious but the maths, **Aninda** introduces himself and the other characters providing some time clues. **Hardy**'s definition of a mathematician as "a maker of patterns". **Al** attends Ruth's lecture and shows his interest in one specific number: Ruth's telephone number
2.	**Back in time** *BBC Newscasters, Hardy* ----, Harvard 1936	Some BBC announcements provide the historical background **Hardy** delivers a lecture on Ramanujan at Harvard Conference on Arts and Science in 1936.
3.	**R's Death Glimpse** *Janaki, R, R's mother, Hardy* India 26th April 1920	**Janaki** recollects her husband's last hours while **Hardy** delivers his conference on R at Harvard
4.	**Hardy's Death Glimpse** *Gertrude, Hardy* ----	**Gertrude**, Hardy's sister, reads cricket scores to him at his death bed. The scores are all prime numbers.
5.	**Death Train Glimpse** *Ruth* In India, on a train	While travelling form Chennai to Bangalore, **Ruth** leaves her husband a message promising to call back later, but she dies suddenly.
6.	**Al and the Cleaner** *Al, a cleaner* Lecture Hall	As a cleaner asks **Al** to leave the lecture hall, he explains he is there to collect his wife's belongings.
7.	**Call Centre No. 1** *Al, Barbara* London, India	**Al** calls BT to try to keep his phone number. Connected to a call centre somewhere, he engages **Barbara** in conversation.
8.	**Geneva Airport** *Ruth, Al* Geneva Airport	**Ruth** leaves Al a message to thank him for the pleasant evening spent together, finally gives him her telephone number. **Al** calls her back but has to leave a message in turn, he is also developing an obsession with infinity and the no. 72911729.
9.	**Cern Taxi** *Aninda* Geneva	**Aninda** talks to an aunt while he is going to give a lecture on R and string theory at the CERN in Geneva

10.	**3 Conversations Simultaneously** *Al, Barbara, Aninda* London, India, Geneva	Combination of three conversations: cacophony of numbers.
11.	**Locked In** *Al, David* Brunel University	**Al** is locked in Lecture Hall 2 at Uxbridge Campus of Brunel University and makes two phone calls to be released. **David** is in L.A. but promises to do his best to have him let out.
12.	**A Melancholy Experience and Madras: Option 2** *Al, Hardy, Ruth, Shane* Brunel University, Madras,	**Al** reads Hardy's "A Mathematician's Apology" and comes across a passage Ruth had marked for him. The painter, the poet and the mathematician are all said to be after beauty and harmony. Time shift – **Ruth** writes to Al that she misses him while she is at a library in Madras. She is also enthralled by the beauty of maths as she holds R's notebook in her hands.
13.	**CERN Lecture** *Hardy, Al, Aninda* Geneva	In his lecture at the Geneva CERN in 1936 Hardy introduces the figure of R as "the most romantic figure in the recent history of maths".
14.	**Hardy's Lecture** *Hardy, Aninda* Harvard, 1936	**Hardy** makes two points in his lecture on R: first his figure escapes all the human canons, second he was "a very great mathematician". **Aninda** paves the way to the following scene: reconstructing the day.
15.	**Reconstructing the day** *Aninda, Hardy, Ruth, R* Cambridge Trinity College, Madras	The day when **Hardy** got R's first letter is carefully brought back to memory with Hardy's daily routines and his request to Littlewood to look into the letter contents.
16.	**Excitement and Not Coming** *Aninda, Hardy, Ruth, Al* Cambridge Trinity College, India	**Aninda** quotes Bertrand Russel from whom we learn that Hardy was terribly thrilled at the idea of inviting R, a second Newton according to him, to go to Cambridge. While travelling by train from Chennai to Kumbakonam, **Ruth** leaves Al a message: she is not going home despite what she had previously promised him.
17.	**Lecture on Convergence** *Al, Ruth, Captain, Hardy, R* Brunel University, on a plane, Cambridge Trinity College, India	In an effort to leave something of permanent value behind, convergence becomes a keyword. As **Al** asks **Ruth** if she wants any children, Ruth deals with mathematical creativity while he is interested in procreativity. A **captain** apologizes for a bumpy flight due to the air pockets arising from the convergence of weather systems. A glimpse of **Hardy** and **R'**s early correspondence.
19.	**The quiet carriage** *Ruth, Surita* Train	On the train from Chennai to Bangalore **Ruth** meets **Surita**. They compare impressions of India.

20.	**A journey** *Aninda, Hardy, R.* ---	**Hardy** tries to make **R**'s journey to England smooth; **R** leaves India by ship. Cut to plane. Altitudes and latitudes as fascinating numbers.
21.	**The Ramada Inn** *Al, Surita, R* Heathrow (London)	**Al** enters his hotel room, which is not ready. **Surita**, the cleaner, comes to make his bed. Tourist info about Cambridge. **R** in Cambridge writes to his friend Krishna Rao.
22.	**Partitions** *Ruth, Hardy, Aninda, R, Al* ----	**Aninda**/**Hardy** talk about partitions. **R** remembers that he and Hardy found a formula that gives the number of partitions for any number. **Ruth** tells **Al** she is pregnant.
23.	**Call Centre 2** *Al, Barbara* Brunel lecture hall	**Barbara** calls **Al** from a call centre, she has not done what Al had asked her about a phone number. **Al** finds out she is calling him from India.
24.	**Alex can't sleep** *Ruth, Al* at home	**Ruth** speaks of R as a little boy. **Ruth** and **Al** discuss about themselves and maths.
25.	**Papers** *Ruth, Aninda, Janaki, Hardy, R* Madras - Cambridge	**Ruth**, **Aninda**, **Janaki**, **Hardy** describe different situations in R's life/work. **R** himself describes how easily he found the solution of an important math problem. **R** tells of his only problem at Cambridge, food.
26.	**Miscarriage** *Al, Ruth* at home	**Al** and **Ruth** are talking about math. **Ruth** finds herself bleeding.
27.	**World War I** *Hardy, Jackson, Ruth, Victoria, R, Aninda* Cambridge	**1914:** **Hardy** asks himself whether mathematics does harm. **Ruth** compares composition in biology to composition in math. **R** writes to his mother "there is no war in this country". **Victoria** decomposes the number of dead, wounded and missing people in First World War as a product of prime factors.
28.	**Distance and decline** *Ruth, Aninda, R, Hardy, Al, doctor* ---	**Ruth** gives a lecture on 0. **R** is ill and in hospital. **Al** is worried about **Ruth** having to go to India. **Hardy** proposes R for a fellowship of the College.

29.	**1729** *Aninda, Hardy, R* Hospital in Putney	**Aninda** illustrates a conversation between **Hardy** and **R** in hospital
30.	**Ruth an Al argue** *Ruth, Al* at home	**Ruth** and **Al** discuss about the reality of mathematics. The two argue about Ruth's decision to go to India and the argument expands on other burning issues, like the loss of their child.
31.	**Death train in silhouette** *Ruth, Surita* train	**Ruth** declares her interest in mathematics as a creative art. **Ruth** dies. **Surita** calls Al.
32.	**Funeral scene** *Hardy* India	R is dead, **Hardy** remembers him.
33.	**Exploding chair** *Ruth* ---	**Ruth** explains the difference between physical reality and mathematical reality
33.a	**Al decides to go to India** *Al, David, cleaner* Brunel lecture hall	**David** asks Al where he is and what he is doing
34.	**Flight to Madras** *captain, Aninda, Al, Hardy* plane to Madras	**Al** and **Aninda** meet on the plane for Madras and exchange opinions on the future of India.
35.	**Madras library** *Ruth, Aninda, Al, R, Hardy, Janaki, Gertrude* Madras, ---	Al and Aninda talk about their interest in R. **Aninda** explains the importance of R's work for the comprehension of physical laws. **Al** and **Aninda** go down to the Cauvery river. **R** writes to Hardy about interesting functions he has discovered. **Hardy** writes to R about new exciting problems to work on. R dies assisted by **Janaki.** Hardy dies assisted by **Gertrude**
36.	**Cauvery** *Al, Aninda, Barbara, Ruth* Madras	**Barbara** calls Al, she has finally managed to transfer the number requested to his name. **Al** tells Aninda about Ruth's death. **Aninda** tells Al his aunt has died. **Al** and **Aninda** honour their dead by the river.

4. BACKGROUND NOTES

The following material focuses ***on mathematical and cultural*** *concepts that can help your students to understand the play.*

4.1 A short outline

This play deals with the life and work of the mathematical genius Srinivasa Ramanujan (1887-1920) a self-taught genius born near the banks of the Cauvery river (sacred to Hindus) in Southern India. A poor clerk, he achieved recognition for his talent shortly before World War I and was taken to Trinity College, Cambridge University, where he collaborated with some of the finest mathematicians of his time, in particular G. H. Hardy.

4.2 Features of the play

The play combines significant flashes from Ramanujan's life in India and in Cambridge with the story of a modern couple: Ruth, a mathematics lecturer fascinated by Ramanujan's life and his legendary notebooks and Al, a student of Indian extraction. Another Indian, Aninda Rao, expert in theoretical physics and string theory acts as narrator.
The play also explores the fascinating world of numbers and examines the role that they play in our everyday lives: from the metaphysical (the Infinite as death or life after death, relationships as convergence and divergence between people) to the mysterious appeal of particular numbers (telephones, altitudes, latitudes, etc).
Other issues touched on in the play are the contrast between East and West, the role of Indian emigrants all over the world and the prejudice they face, as well as the horrors of war.

4.3 Ramanujan and Cambridge

Ramanujan faced many difficulties in Cambridge: separated from his young wife and his mother, in a climate totally different from his own, with food which posed severe problems for him, since he was a Brahmin (a high ranking Hindu caste) and a vegetarian, even such items as shoes and bedclothes were totally alien to him.
Trinity College, Cambridge was also an unusual environment. Cambridge was and is a **collegiate university**: a university whose functions are divided between the central administration of the university and a number of constituent colleges.
Independent colleges vary in the level of teaching that they provide, but they may create positions independently from the university and may provide their own funding for research. They also tend to play a large role in deciding admissions. Students become members of the University through membership in their particular college, and matriculation is often done through, or at the behest of, the colleges.
Trinity has always been one of the richest colleges, and in 1913 was a self-contained community governed by a Master and a group of Fellows, often known as Dons, elected for their academic merits. The medieval monastic spirit survived: there were no women students in Trinity until 1978! Fellows who married had to live outside the college while many Dons, like Hardy, were confirmed bachelors and had beautiful suites of rooms inside the College. Isaac Newton went to Trinity College, Cambridge, and the college has always had a strong tradition in Mathematics and Physics.

4.4 Ramanujan's Mathematics

From the mathematical point of view, Ramanujan proceeded by incredible leaps of intuition, and his insights had almost the quality of divine inspiration (in fact he claimed that his most important discoveries came to him in dreams and were written on his tongue by a Hindu Goddess). The concept of a rigorous, step-by-step proof was foreign to him, but Hardy had no doubt that he was possibly the greatest mathematical genius in 500 years.
In collaboration with Hardy and other mathematicians, he achieved many fascinating results, which are still being exploited today, but after some time he fell ill.
In 1919 he returned to India and died shortly afterwards. He is now revered as a national hero.
Many of Ramanujan's imaginative results are still being analysed and understood; others find application today, even in such fields as string theory, an exciting new branch of theoretical physics.
Many of his most important results are in two areas: the theory of prime numbers and the theory of infinite series.

4.5 Basic Mathematical Concepts

4.5.1 Prime Numbers

(adapted from http://en.wikipedia.org/wiki/Prime_numbers)

In mathematics, a **prime number** (or a **prime**) is a natural number which has exactly two **distinct** natural number divisors: 1 and itself. An infinitude of prime numbers exists, as demonstrated by Euclid around 300 BC.
The study of prime numbers is part of **number theory**, the branch of mathematics which encompasses the study of natural numbers. Prime numbers have been the subject of intense research, yet some fundamental questions have been unresolved for more than a century. The problem of modelling the distribution of prime numbers is a popular subject of investigation for number theorists: when looking at individual numbers, the primes seem to be randomly distributed, but the "global" distribution of primes follows well-defined laws. The theory of large primes today finds application in encryption algorithms for automatic cash machines for example.
Infinite series (adapted from http://en.wikipedia.org/wiki/Infinite_series)

In mathematics, a **series** is often represented as the sum of a sequence of terms. That is, a series is represented as a list of numbers with addition operations between them, for example this arithmetic sequence:

> 1 + 2 + 3 + 4 + 5 + ... + 99 + 100
> "One plus two plus three plus four plus five plus dot dot dot plus ninety-nine plus one hundred"

A series may be finite or *infinite*. Finite series may be handled with elementary algebra, but infinite series require tools from mathematical analysis if they are to be applied in anything more than a tentative way.

Examples of simple series include the arithmetic series which is a sum of an arithmetic progression, written as:

$$\sum_{n=0}^{k}(an+b);$$

"The sum of a-n plus b as n goes from zero to k"

and finite geometric series, a sum of a geometric progression, which can be written as:

$$\sum_{n=0}^{k} a^n.$$

"The sum of a to the nth power as n goes from zero to k"

4.5.2 Infinite series

The sum of an **infinite series** $a_0 + a_1 + a_2 + \ldots$ is the limit of the sequence of **partial sums**

$$S_n = a_0 + a_1 + a_2 + \cdots + a_n,$$

"S-n equals a-zero plus a-one plus a-two plus dot dot dot plus a-n"

as $n \to \infty$ ("as n tends to infinity"), if that limit exists. If the limit exists and is finite, the series is said to **converge**; if it is infinite or does not exist, the series is said to **diverge**.

Infinite series of nonzero terms can converge, which resolves the mathematical side of several of Zeno's paradoxes. The simplest case of a nontrivial infinite series is perhaps

$$1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \frac{1}{16} + \cdots.$$

"one plus one half plus one quarter plus one eighth plus one sixteenth and so on"

This series is a geometric series and mathematicians usually write it as:

$$\sum_{n=0}^{\infty} 2^{-n} = 2.$$

"the sum of two to the minus n as n goes from zero to infinity equals 2"

An infinite series is formally written as

$$\sum_{n=0}^{\infty} a_n$$

"The sum of a-n as n goes from zero to infinity"

where the elements a_n are real (or complex) numbers. We say that this series **converges to** S, or that **its sum is** S, if the limit

$$\lim_{N\to\infty} \sum_{n=0}^{N} a_n$$

“the limit as big N tends to infinity of the sum of a-n as n goes from zero to big N”

exists and is equal to *S*. If there is no such number, then the series is said to *diverge*.

4.5.3 String Theory

(adapted from http://en.wikipedia.org/wiki/String_theory)

String theory is a still-developing scientific approach to theoretical physics, whose original building blocks are one-dimensional extended objects called strings. Unlike the point particles in quantum field theories such as the standard model of particle physics, strings interact in a way that is almost uniquely specified by mathematical self-consistency, forming an apparently valid quantum theory of gravity.

String theory itself consists of many theories with different mathematical formulas. The logical coherence of the approach, however, and the fact that string theory can include all older theories of physics, have led many physicists to believe that such a connection is possible. In particular, string theory is the first candidate for the theory of everything, a way to describe all the known natural forces (gravitational, electromagnetic, weak and strong) and matter (quarks and leptons) in a mathematically complete system. On the other hand, many detractors criticise string theory because it has not yet provided experimentally testable predictions.

String theory is of interest to many physicists because of the mathematics involved, and because of the large number of forms that the theories can take. String theory strongly suggests that spacetime has eleven dimensions, as opposed to the usual three space and one time, but the theory can easily describe universes with four observable spacetime dimensions as well.

5. Teaching/learning activities

*The following activities are suggested **before seeing the play.***

The first six exercises have been especially chosen in order that students may

- *experience physically how numbers have their own characters, and different numbers have different characters*
- *discover how maths might be the basis for everyday movement: an apparently casual sequence or a dance*
- *see how creative a mathematical proof can be*
- *learn how movement may be used to express abstract ideas such as infinity*

5.1. Exercises from www.complicite.org

1. Exercise - Partition Theory

One of the mathematical formulae that R and Hardy worked on together predicted the amount of partitions that a number has. The partition number is the number of ways that an integer can be expressed as a sum.

For example, there are three partitions of 3: 1+1+1
2+1 and
3

There are five partitions of 4: 1+1+1+1
2+1+1
2+2
3+1 and
4

In groups of five, six or seven arrange yourselves spatially into the all of the possible configurations for your group number. Pay particular attention to the order you choose to do the partitions in and how you move between the various arrangements.

How do you remember the moves?
Does the number of people in your group lead to a particular set of shapes, spaces and movements?
Does the final sequence of movements suggest a dramatic narrative or dance?

2. Exercise - Articulating Actions

Choose a simple action: for example reading a newspaper or drinking from a bottle. Deconstruct the action into a repeatable phrase with a set number of movements punctuated by distinctive articulation points (i.e. where each sub movement begins and ends). Practice your phrase so that you can move on each articulation point as if to the regular beat of a metronome. One person can count or beat time to make this clear. The movement should appear quite mechanical. Then choose a number between 1 and 7 and only move on multiples of this number, or choose a sequence of numbers like square numbers or primes and only move on these.

What happens to the action?
Observe when this makes the action organic, comic or when it reads as a specific attitude to the action.

3. Exercise - The dynamic of numbers

When we think about numbers we each get instant mental images: 3 might conjure the figure 3, three objects, a triangle, or three dimensions. Numbers are all unique and have distinctive qualities. As theatre makers we explored how each number might be expressed as sound, rhythm or movement. We started by exploring the positive whole numbers, then we explored negative numbers, rational and irrational, and imaginary numbers.

Try to express different numbers in sound, rhythm or movement.
Is there an intrinsic physical dynamic to a number?

4. Exercise - Layering stories

Choose three sources that have only oblique connections: perhaps a newspaper story, a photo and a poem. In groups find a way to integrate or layer all three sources and find one moment where the three sources come together or converge in some way.

It seems that mathematical ideas are arranged somehow in strata,
the ideas in each stratum being linked by a complex of relations both among themselves and with those above and below.
GH Hardy: A Mathematician's Apology

The process of devising involves experimenting and discarding numerous ideas, throwing ideas together and allowing the possibility of the unexpected. ... Mathematics works in the same exploratory way.

A mathematician is a pattern searcher.
Maths is about finding patterns in the chaos of numbers that surround us
Marcus du Sautoy

5. Exercise - Counting game

One person counts from one upwards rhythmically and clearly so everybody can hear. Each other participant chooses individually which number series to move on (again: primes, squares, multiples, odd numbers etc). The movements are really simple: walking, sitting, rolling. The exercise reveals the rhythms, patterns and spaces between different number series. Narratives emerge as observers instinctively search for or try to predict patterns and are surprised when something happens that doesn't match their expectations.

6. Exercise - Repeating patterns and infinity

In groups of three, four or five create a movement pattern that can repeat indefinitely. Do these movements suggest infinity?

Then try to express infinity using movement.
What is the difference between a repeating pattern and a movement pattern that suggests infinity?
What do we really believe will go on forever?

7. Exercise - Read the summary below of **A Disappearing Number** and find out:

1. The names of the two historical figures who started one of the most fruitful collaboration in maths history.
2. The main juxtapositions in the play
3. The idea that conveys unity to the play
4. Cross-cultural references

A Disappearing Number takes as its starting point the story of one of the most mysterious and intriguing mathematical collaborations of all time.
Simultaneously a narrative and an enquiry, the production crosses three continents and several histories, to weave a provocative theatrical pattern about our relentless compulsion to understand.
Threaded through this pattern of stories and ideas are questions: about mathematics and beauty; imagination and the nature of infinity; about what is continuous and what permanent; how we are attached to the past and how we affect the future; how we create and how we love.
A man mourns the loss of his lover, a mathematician mourns her own fate. A businessman travels from Los Angeles to Chennai pursuing the future; a physicist in CERN, Geneva looks for it too. The mathematician G H Hardy seeks to comprehend the ideas of the genius Srinivasa Ramunajan in the chilly English surroundings of Cambridge during the First World War. Ramunajan looks to create some of the most complex mathematical patterns of all time.
We are all looking. The question is: who can see?
"People like us who believe in physics, know that the distinction between past, present and future is only a stubbornly persistent illusion".

Einstein

8. Exercise – Before seeing the performance debate the following issues in pairs:

1. East is East and West is West and never the twain shall meet (Kipling)
2. Religious belief and personal fulfilment
3. Are geniuses bound to suffer as they are usually held out of this world?
4. Intuition in the development of scientific thought
5. Compare the ultimate task of painters, poets and mathematicians and find how much they share

Follow-up activities after seeing the play to be made available at a later date.