Le-MATH

Learning mathematics through new communication factors

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MATHeatre

Teaching and learning mathematics through mathematical communication activities

Guidelines for Teachers and Students

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1. What is the aim of MATHeatre?

Background and Rational

Unfortunately, many pupils as well as parents consider mathematics to be a difficult and boring subject. Instead of studying mathematics (and other subjects) many pupils prefer to spend most of their time watching TV, playing electronic games or exchanging messages, photos, videos and playing games on their mobile phones, One way to attract pupils back to the “playing field” of education is to use similar tools (weapons) to compete with their “opponents”. That is to communicate the learning of mathematics using non-traditional methods such as with games, through theatre or using competitions similar to the well-known X-Factor etc.

Many pupils claim that mathematics is too abstract and therefore non-approachable. This proposal uses a completely different and new approach by inviting teachers and pupils to apply new communication methods of learning mathematics, which are fun, enjoyable and functional at the same time. The pupils can “play and learn”.

“The aim of the MATHeatre is to encourage students to stimulate the imagination of the public and express mathematical ideas using theatrical skills to a non-specialist audience.”

Why Mathematics Theatre?

The idea is to make the study of mathematics more attractive through theatre.
Theatre activities in maths education have the potential to act as an important tool for development of students' comprehension, encouraging their motivation and diminishing their preconceptions that mathematics is too abstract. The use of these activities in mathematics teaching can help teachers make maths lessons more enjoyable both for students and themselves.
Suggested scripts and concrete examples of theatrical experiences are available in these guidelines and in the Le-MATH Manual of Good Practices as well as on the project website.

2. Introduction

Since ancient times great mathematicians have used oratory to communicate their knowledge. Through the rhetoric and the forum, they shared their knowledge and enabled the diffusion of major theories: Trading permitted widespread access to a vast amount of knowledge. Through theatre we can imagine doing the same as theatre makes it possible to reconstruct this process of dissemination. Also staging concepts and characters would allow our students a better understanding of concepts that seem often intangible.

Advantages of the introduction of theatre into teaching practise are numerous. Indeed, theatrical techniques are often used in special pedagogical or socio-cultural situations such as the learning of a foreign language, for personal development, or to aid enthusiasm of a group, so why not in a mathematics session?

The universality of mathematics allows every mathematics teacher to use such a method, as a tool to succeed in teaching their subject. Our objective in this guide book is to present a methodology which is able to be used whenever you want to introduce theatrical activities into your sessions or workshops.
This methodology is also the one that the participants of the" Le-Math Theatre competition" will have to follow to compete.
You will be able to write your own scripts or use those already written as included.
Also included are criteria to test your students in such activities, and criteria for the competition.

Using theatre in mathematics presents many interesting challenges for the class. The teacher is the stage director...
In this way we can create a dynamic in the group where each student can exchange ideas, give input, listen and share with the pleasure of working together.
Each student can also develop a socio-cultural awareness, autonomy, an open mind, imagination,

creativity and self-discovery with the help of the teacher and learn to cope with the experience of performing in public and improving their self-confidence and self-expression.

Theatre reinforces the notions of sharing. Acceptance of authority is integrated in a playful frame. Given instructions are more easily accepted.

That's why the creation of communication situations and a real exchange (initial preparatory work in the class, rehearsals, final production, and the performance) around a mathematical theme, as a pretext to using a specific language can be practised in a theatrical context.
Students will learn to bring out, unlock and fluidize their speech, improve their memorization during rehearsals, and will be enabled to think and reason by using the language of mathematics, rendering this subject less “foreign” by working intensively with it. This approach will consolidate learning, enable work on rhythm, melody and intonation, sounds and tonalities (Multiple Intelligences: musicality), learning in general and especially for younger children there will be improvements in attention, concentration and listening to each other.
Theatre is an art which mixes, amongst others, music, dance, comedy, and leads to a discovery of the related jobs of sound control, lighting, set building, costumes, make-up...
And more than that...the pleasure, the game!
The entertaining aspect is promoted to lessen the effect of the restraints of learning. The first interest has to be the pleasure and the game and not the learning. However we have to be careful! Theatre is not a miraculous solution, but first and foremost, a ludic and artistic accompaniment to learning.

That is the reason why teachers need to take account of the following points in order to succeed:

- **The first point should be the heterogeneity of groups:**

Generally, most pupils are happy to practice theatrical activities. However, it may happen that the enthusiasm is not shared by everyone:
There are two types of students (extrovert or introvert) to take into account: the students who are failing in maths or who have been suffering from a long term blockage on the subject for a long time or are simply demotivated by the subject; then there are the successful students who are interested or who have a gift for mathematics.
For the first group this new method will enable them to approach mathematics in a fun way, using other personal qualities rather than their mathematical potential (multiple intelligences).
The second group may not see the point of this new approach as they are already successful in that subject. There is a risk of them having a negative attitude towards this new practise and they may even be most hostile. However they need to be convinced that the usefulness of the method for them is to express mathematical notions, verbalize them, explore them in a completely different way and relate these notions to the audience, rendering the basis of learning to a greater depth.

In both cases, pleasure is the means to meet the objective (Multiple Intelligences: inter-personal and team work at all stages.)
The pleasure to share with the other students, to learn together (rehearsals) and at the end to perform together (the play); a fierce link is created between the students but also between the teachers and the students, which is a special situation appreciated on both sides.

There may be students who still resist this technique itself: students who don’t like theatre, who are too shy or have other reasons for refusing to be actors:

(Fear of being ridiculous, fear of being judged or a fear to deceive the learners.)
They can still be involved in other important roles bringing out their strengths as offering technical support, writing, directing, costume, set, makeup and so on.

- **Other points for teachers:**

The aim of such activities is not that they should be carried out continuously throughout the year but maybe once, or as a workshop where you are not confined by the curricula.
Moreover, some teachers are afraid of losing precious teaching time and that they will have no marks for their students. In this guidebook, you'll find criteria that will help you to evaluate your students if needed.

Some teachers worry about a lack of training or information in these practises:
Fear of not being able to maintain coherence between mathematical lessons, objectives or the support lessons and the theatre and a fear getting out of the classical frame of teaching or losing the role being in charge.
There are worries about dealing with the whole concept of theatre and drama. However it is not necessary to perfectly master drama to use its techniques but it is important to be able to manage a group and the problems associated with it. And teachers are generally well able to do this!

There may be different problems to deal with than those we are used to in the classroom: too much noise, disturbances, excitement from the young ones. There may be difficulties in managing noise levels and new tactics need to be deployed. Some theatre trainers use ~~the~~ sign language: raising and waving hands to avoid the noise in the classroom. Applause is an important part of the play as it is way for the audience to interact.
Teachers have to calm the more boisterous learners and to encourage those that are more timid and we need be sure of our ability to realize such a project for the interest of everyone involved.

So what qualifications are needed to begin this theatre practise?
It is certainly an advantage if the trainer has had experience in theatre but it is not necessarily a requirement. Most people have seen at least one play or have read a play. (E .g. Romeo and Juliet)
It is not so difficult for teachers to become actors or stage directors: We teachers are like actors on stage as soon as we enter our classroom! We have our public and we must convince our audience of the truth of our knowledge using rhetoric, drama etc. Just in the way that famous mathematicians, thinkers or philosophers have done for centuries...

The role of the teacher is to create a fun atmosphere beneficial to the game, to reassure the learners and to encourage their participation. The teacher needs to instil a sense of mutual respect, to establish a non-judgemental atmosphere where humility and collectivism are important as well as allowing imagination to thrive.

From the most reluctant to the most motivated, let’s now look how we can integrate theatre into our mathematical practises and lead our students to increased comprehension and interest for the subject.

3. Methodology

3.1 Different types of theatrical activities

It is possible to set up a theatre activity in the mathematics lesson in different ways depending on the objectives, but also depending on the number of sessions the teacher chooses to use for the work.

a) To discover a new concept:

The setting of a theatrical activity can help the teacher to introduce a new concept. In this way, the teacher can prepare a discovery activity that will allow students to become familiar with new content.

Role plays are appropriate to explain mathematical methods where each student has a specific role in the game, e.g. exploring proper or improper fractions and mixed numbers, simplifying fractions, or solving equations …

Gerofsky (2011) claims that "the whole group improvisation drama in an « as if » setting engages students through immersive emotional and contextual modes of understanding ". Using theatre to teach mathematics involves acting, which is qualitatively similar to children's spontaneous role-playing.

Pallascio and Lajoie (2001) study role-playing as an efficient tool for making students active in a given situation. The objective of theatre activities, similarly to role-playing, when used in teaching contexts, is to lead student-actors and other student spectators to learn something from the given situation. When dramatizing a mathematical concept, pupils use facial expressions, role-playing, improvisation etc. They work in groups and improve their understanding of mathematics through writing scripts and playing the theatre.

The activity is conducted before the lectures. Its length is relatively short.

b) To reinvent a concept.

The use of theatrical activity could also be used after studying a concept following the theory and the classical training exercises. Acting a play or writing a script is a good way to master a concept.

The teacher must decide how much time should be given for the activity.

i). Setting a short activity.

The teacher can choose an activity as a sketch. This can be done at the end of a work session. The sketch uses a small number of students and takes place in the classroom. It focuses on a single concept.

ii). Setting a longer activity.

A play is a good way to master a concept. The teacher can organize an annual or biannual project. The activity can be done in class or in a workshop. One or more sessions per week can be made available for the theatre workshop.

At the end of the year, a show could be put on. This could focus on a broader mathematical content combining several concepts studied during the year.

3.2 Theatrical approach

You need to think about your goal (will it be on a smaller scale looking at one concept or one sequence in a shorter time or will it be a larger project). You should involve the students from the beginning explaining and developing the project with each other by exchanging in class and you should ask one of them to take on the role of the secretary before creating the staging.

3.2.1 Theatrical bases:

It is best if a script is created within the group with the full involvement of the students keeping in mind that the play will be shown to an audience either within the classroom or to a larger public. The teacher needs to oversee that the language of communicating notions is appropriate.

As an example, you can then show them an extract of a play:
E.g. Romeo and Juliet, (see further below)

Before beginning with a script we can use photos or sketches or even paintings and imagine characters speaking about a mathematical concept.

e.g.:

A classroom

A real stage

A painting

Before writing, it's useful to look at theatrical terminology

Technical theatrical terms are very easy to understand:

A theatrical text is primarily a text composed of two strands: There is the dialogue between the characters, and then there is the stage direction that specifies the place, the time, the protagonists and their reactions during the course of the action. This whole text with its two strands conveys the concepts of a play using the scenic conventions: defined and delimited space, acting, lighting, cutting, sets, and the presence of an audience.

3.2.2 Glossary:

Aside: a dialogue or action to be heard or seen by the audience while escaping the other characters.

Confidant: a secondary character who receives the confidences of a main character, which allows the viewer to be aware of the facts necessary for an understanding of the action.

Court garden: the court refers to the right side of the stage from the audience, the garden side, the left. These terms have been passed down from the Theatre of "The Tuileries".

Design: Consideration of all the technical organization of the scene and its relationship with the audience.

Dialogue: all words exchanged between the characters in a play.

Didascalie: an indication of staging provided outside the text of the play.

Dramaturgy: all theatrical techniques used by an author.

Misunderstanding: theatre effect exploiting a mistake.

Monologue about a character, alone on stage, stands to himself revealing his feelings to the viewer. Formed by this type of tirade scene.

Play offices (branches): seating

Protagonist: the main actor.

Reply: part of the dialogue delivered in one piece by a character.

Stage director: a person who develops and oversees the performance and ensures its unity.

Story: a longer development dialogue usually given by secondary character, stating facts that have taken place off stage.

Theatrical or dramatic writing: all elements that give a text its theatrical power.

Tirade: a long reply.

Below a concrete example of a theatre text: Shakespeare's "Romeo and Juliet "

Romeo and Juliet (Title)
Shakespeare :(Author)
Act II, Scene II (context)
(You can also report the time and place)
Romeo (character name): He laughs wounds, who has never received any injury! (*Juliet appears in a window didascalie*)… But soft! What light through yonder window? This is the East, and Juliet is the sun! Arise, beautiful dawn and kill the jealous moon, already languishing and pale with grief, because you, her priestess, you are more beautiful than herself! Am no longer his priestess, since it is jealous of you, her vestal livery is sickly and pale, and only the mad are: reject it...! This is my lady! Oh! This is my love! Oh! If she could find out! ... What does it say? Nothing ... It was ... But no, her eyes speak, and I want to meet him ... This is not me it is addressed. Two of the most beautiful stars, dealing also adjure his eyes will shine well in their spheres till they return. Ah! if the stars were substituted in his eyes, at the same time his eyes to the stars, only the brightness of her cheeks would fade the brightness of the stars, as the big day, a lamp, and her eyes from heaven, a darderaient such light through the air regions, the birds sing, believing that the night is over. See how she presses her cheek upon her hand! Oh! Why am I a glove upon that hand! I'd touch her cheek! (Rant)
Juliet Alas!
Romeo: It speaks! Oh! Still talking, shining angel! Because you shine in the night, over my head, like the winged messenger of heaven, when the eyes of mortals who upset reject back to contemplate, he beats the lazy clouds and sails upon the bosom of the air!
Juliet: Oh Romeo! Romeo! Wherefore art thou Romeo? Deny thy father and refuse thy name, or if you do not want sworn my love, and I will no longer be a Capulet.
Romeo, Do I still listen or respond? (*Replicas, Idem*)
(...)

Then we must answer the questions: Who? Where ? What? When? How? (The well-known five W's!)
In this extract, we have the two characters, two lovers using particularly eloquent words; the place where they meet: a garden, a balcony (very romantic); the moment: during the night and also the lyric tonality used in the dialogue without forgetting didascalies useful for characters and staging/setting director.

We must think indeed about the tonality: do we want to use comedy or fear or another feeling or remain neutral?

Before writing we should try different exercises to put the students in a creative frame of mind: these could be oral and space position exercises. This is good fun for everybody.
We can ask them to repeat some difficult words and move around the class looking at space and relationships between others (examples in the appendices)
Students can write their text individually or in groups). The group then needs to decide who has the best ideas or text and script. Then roles need to be appointed.

After that, we can prepare the show...
For theatre, "one needs "three boards, two actors and "one passion" (Spanish writer Lopez de Vega, Madrid, 1562 – 1635)
The „theatrical" space must be used efficiently.

- Space may be about anything, from simple to elaborate recreations of something (from a simple chair, the intricate setting of a building, a sheet, a forest, open air spaces, etc.)- Choice of effective yet simple styles of architecture, decor, furniture, costumes belonging to a certain time period.

- The set should aid the performers providing them with an appropriate background so as to create mood and atmosphere.
- Anything goes; there's no established style of scenic production.
- Creating realistic stage settings is a difficult, costly endeavour – abstraction is better (limited budgets do not allow for realistic stage settings therefore the building of mini stages is preferable.
- The set design must reflect the artistic vision of a production in the most effective ways.
- The audience must be convinced that they are witnessing something happening in a particular time and place – the set a naturalistic, realistic or authentic recreation of a particular location (e.g. a temple, a palace, seashore, a room, etc.)
- ”Timelessness” can be achieved by an amalgamation of styles.
- Set designing should convey the setting without taking away from the actors.
- It is advisable to use non- illustrative scenery (merely suggesting the setting of a scene or play) rather than an actual one (a closer reproduction of a specific place, which is more elaborate and expensive and time consuming).
- The choice of a structured and/or spontaneous exploration of space, time, shape, sound, motion so as to attract and hold the attention of the audience.
- Set and costumes but also lights and props – should reflect the themes, mood, style and the emotions of a play/scene, indicating the historical or geographical context of the play.
- The visual aspect of a performance can be extensively developed so that it may become the major emotional element affecting the audience.
- All theatrical visuals, set, costumes, lights, props, must work in harmony and need to homogenous and incorporated into the bigger picture (all come as pre- established considerations)
- The set can be colourful, pastel or monotone
- The interplay of light and dark on the stage
- Possibility of combining the classical and the contemporary worlds (e.g. fragments of Greek columns, pieces of modern furniture, etc.)
- The set should indicate the time period, the time of the day, the season
- Types of common scenery: curtains, platforms, beams of lights, scenery flats (flat pieces of theatrical scenery which are painted and positioned on stage to give the appearance of buildings or other scenes for a background); spotlights, etc.
- The use of an open stage, in the round – (actors are nearer to more of their audience, and are better seen and heard and are more aware of their audience.

3.2.3 Ideas for Costumes

- Ariane Mnouchkine (le Theatre du Soleil): „ Finish your costumes well. They can be your friends. They are your enemies if they are badly made”. – costumes must be
- Lively, rich/simple, finished, exact, closely related to set
- Should reflect the status and individuality of different characters – decisions made on their significance and importance (how much weight do they carry in the play?)
- Costumes locate the chosen historical period, the geographical location of the play
- Reflect the character's personality either naturalistically or symbolically (poverty, health, accessories like jewels, makeups, hairstyles, etc.)
- Tell about the different seasons of the year, weather conditions in which the scene is set, the time of the day (e.g. morning pyjamas, at the beginning of the play, summer frocks in

the afternoon, evening dresses towards the close of the day, etc.)

- Reflect a character's age, profession or occupation (e.g. choice of fabric, - coarse, simple fabrics to express poverty, whereas shiny smooth fabrics convey wealth, royalty, etc.)
- Masks as part of a costume – only if it adds to the dramatic effect
- Costumes should enhance students 'abilities to communicate, interact and move (body movements not to be affected by clothing)
- Special effects – to render mood and atmosphere ranging from simple to more sophisticated approaches (smoke, fog, rain, snow, use of flashlights, etc.)
- Hard props
- Larger props (furniture…)

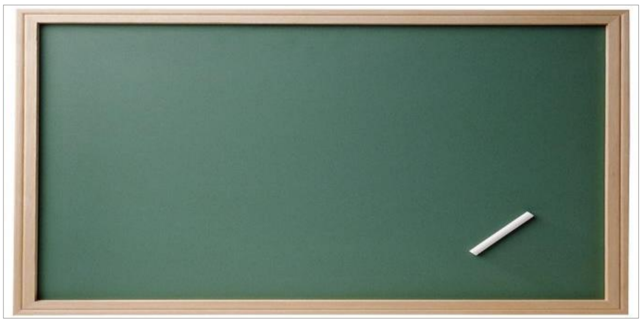
◆ stage space: transforming a classroom ...

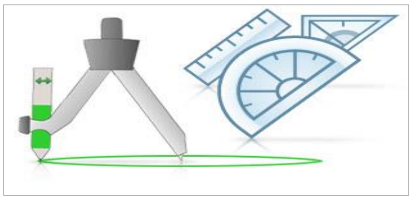
If we have an auditorium with a stage, backstage, curtains and lighting, several types of sets could be considered and the definition of the stage space could be simplified
Then, we can choose to make the public participate or not (Mnouchkine)

◆ behind the scenes, backstage : may be the door to the classroom
◆ decor: curtains can also become input and output's places for the characters

The blackboard can also become an element of the decor



◆ <u>Music:</u> background music is always interesting to use, to create an atmosphere.
◆ <u>Accessories:</u> use the class material ... a ruler becomes a sword, a sheet of paper becomes a parchment... create a mask for an emotion



- costumes: a simple sheet/towel can become a toga
- Use timing appropriately (length of the play or the scene)

And then;

- Before the performance, dialogues will have been learned, stage positions will have been practiced and characters and will have developed some oral fluency
- After the show, all participants will be invited to express their opinions and share their impressions and to eventually to write a summary of the performance
- A (self-) assessment grid could be useful for this activity and a video could be a good way to review achievements and help in respect of making improvements

3.2.4 Feedback

- Discussions between the student-actors and the student spectators about the mathematical notion or the play are a good way to verbalize and clarify any difficulties.
- Self-evaluation: videos can be used and are a good way to realize the mistakes and help the students improve.
- A criteria sheet to help if an assessment is required

Assessment criteria of the theatrical activity in class

The two empty columns are here regarding different ways of marking in the different countries in Europe (A, B, C/0-10/no mark)

I – <u>Mathematical content</u>

The student has approached a mathematics concept studied in class	
The student was able to clearly stage the concept	
The student has represented a theoretical concept within a supporting framework	

II – <u>Theatrical aspect</u>

The student feels at ease/confident in front of others and expresses himself correctly	
The student uses the available space well	

The student has responded to the given instructions.	

III – Creativity of the staging

The student is involved in its delivery with consideration to the rest of the team	
The student demonstrates originality (e.g. music ...)	

3.2.5 Useful templates

Samples of play sheets to be recorded in a teacher's data base. (Level, number of participants, subject, time, preparation, process.)

Sheet N°..... : *Title : Solving equations*

Level : *5th/12 years old*

Goals: *Mathematical/pedagogical content: Understanding the technique of solving equations. Enabling the students to grasp a deeper understanding of the mathematical technique of the resolution of an equation*

Length : *15min/1h*

Participation: *the whole class.*

Where? *In the classroom*

Material needed : *one chair, two T-shirt sin different colours*

Pedagogical support : *none*

Preliminary Preparation *Explain the rules of the game.*

Procedure :-

What to do after? *Repeat the process and let the students solve their own equations ~~to solve,~~ find problems and ways to how to solve them.*

Remarks.....

Variants :*Repeat at a more difficult level : e.g. with divisions : x=2/3*

Blank sheet to be filled by teachers from their own experience:

Sheet N°..... :
Level: ……………………………

Goals:…………………………………

Length :…………………………………

Participation : …………………………………

Where ?………………………………………………

Material needed : …………………………………………………

Pedagogical support: ………………………………………………

Preliminary preparation?………………………………………………………

Procedure :-……………………………
-……………………………
-……………………………

What to do after ?…………………………………………………………………………………………………
………

Remarks………

Variants :……………………………………………………………………………………………………

3. 3 Mathematical content and examples

Mathematical ideas sometimes seem to be very theoretical and complicated, despite the fact that it is actually based on logic and a deeper simplicity. The main difficulties in teaching mathematics are related to the fact that some pupils are afraid of mathematics, especially when changing school forms, or moving on to a higher level of studies, e.g. from fourth form to the fifth form. It could be the fact that previously maths has been taught by a non-specialist teacher while in the fifth form the subjects are taught specialists. Similarly, when passing from the upper elementary school to the secondary school, the number of subjects to be studied increases, while the number of hours devoted to mathematics decreases and the curricula is designed to remain the same.
If a maths teacher is motivated to apply new, interesting approaches using new ways of communicating such as the MATHeatre and MATH Factor, the teaching of mathematics becomes an exciting activity.

Any new ideas, methods or tools should be explored to enhance the teaching of maths to increase pupils' interest as these will contribute positively to their attitude to education and to to the subject. For example relating interesting and "mind catching" stories with mathematical content;

applying mathematical knowledge to solving practical problems; exploring the relationship between music and mathematics; revealing the important role of mathematics in arts and architecture; presenting mathematical facts through art or relating sports to mathematics – all of these are promising areas for engaging and encouraging an interest in mathematics and inspiring students to learn mathematics. An outstanding and very compelling example of what can be done using art to attract students to mathematics emerged as a result of a longstanding collaboration between the artist Eugen Jost from Switzerland and Professor Peter Baptist from Bayreuth University in Germany (see www.mathematik-und-kunst.de). The pictures created by Jost have unusual titles such as "Mediterranean geometry", "A walk with Mr Euler", "Hardy's taxi", "Pisa, Cambridge, and Bern", etc. Every one of the pictures however tells us several stories deeply related to mathematics. Moreover, this is done in an interesting and aesthetic way. The paintings of Jost demonstrate convincingly the idea that many fundamentals of mathematics such as designs, structures and patterns, belong to the cultural heritage of our civilization and will enjoy appreciation in the future as well.

Write a play script

You could begin with a mathematical problem, a question, an event related to mathematics, a mathematician, or the history of mathematics. Then you need to try to create a story and develop it in a dramatic situation. Another option is to start with a dramatic event, and try to connect to a mathematical theory.
Support your pupils in writing and completing the script. They need to name the play and of course the characters.

Example 1: THE RIGHT QUESTION

Let's look at the following story/mathematical problem.

You are the leader of a caravan and you need to find the right way across the Sahara Desert You were told, that at one point where the roads fork live twin brothers. One of them always tells the truth and the other always lies; he never tells the truth. Only one of them will be waiting for you in front of their house by the fork, and this brother will only answer one question.
Which question should you ask him to find which is the right way?

There is no use in asking questions like:

"Do you always tell the truth?" The answer in both cases will be "Yes, I tell the truth." Or,
"Which is the right way? "The brother telling you the truth will indicate the right way, while his brother the opposite.

"Which is the wrong way?" The brother telling the truth will point to the wrong way indeed, but his brother will point at the right one so this doesn't help you!
What is the solution in this case? You have the responsibility for dozens of lives, for the lives of the people in the caravan depend on your decision. How can you solve this problem?

The question you need to ask is the following:
"Please show me the way your brother would indicate if I asked him the question: Which one is the right way?"
If the truthful brother is answering you, he will say:
My brother would indicate this way, and he will point to the wrong way –because he knows his

brother in not telling the truth.
If the other brother who lies answers you, he won't tell the truth this time either, so he will answer similarly;
My brother would indicate this way and he will point the wrong way – because he knows his brother would tell the right way, but he of course he will be not telling the truth.

Thus, from both of the twins you now know the wrong direction so you have to choose the other one.

Now follows the invention of the characters, the dialogues, and a dramatic play.
For French pupils the leader of the team could be the Little Prince and they need to find their way to the right planet.
For a Catholic school, the leader of the caravan could be Moses leading his people out from the desert.
For Greek schools maybe Ariadne could lead the team out from a labyrinth.

Mathematical and Pedagogical background of the example

The teacher will be in a good position to initiate discussions about logic, true and false statements, logical value of a statement, logical variables, and the logical operations, negation, double negation, implication, rules for implication, equivalence, conjunction and disjunction.
The students will learn to formulate precise statements and will practice basic logical operations and their properties. The story also enforces the feeling of a team leader's responsibility, the ability to make right decisions after analysing the possibilities.

Example 2: The Wolf, the Goat and the Cabbage

A well-known story, the Wolf, the Goat and the Cabbage shows us how ~~the~~ mathematical reasoning is present in everyday problems, and even game-like logical exercises. In particular the solution of these games present communicational aspects, which are easy to ~~be~~ transform into an activity game type theatre play.

The Classic Problem:

A man once had to travel with a wolf, a goat and a cabbage He had to take good care of them, since the wolf would like to taste a piece of goat if he would get the chance, while the goat appeared interested in the tasty cabbage. After some time on their journey, the man suddenly stood in front of a river. This river could only be crossed using the small boat lying on the shore. The boat was only big enough to take himself and one of his loads across the river. The other two of his belongings, he would have to leave on their own waiting to be transferred. How must the man row across the river back and forth, to take him as well as his belongings safely to the other of the river, without having one eating the other?
Can you make a plan to organize the crossing?

There is a second level option in this game. It entails two additional pieces of luggage - a stick and fire! In addition to the restrictions of Level 1, if the stick and the wolf are left on their own, the stick will beat the wolf! If the fire and the stick are left alone together the fire will burn the stick!

Example 3: Job interview

Applicants for the position of chief accountant of a bank were being interviewed. As part of the selection process they had to answer the following question. As the chief accountant they would be able to give someone a salary increase. The two options are, either an increase of 10% every 3 months, or an increase of 25% each half year.
The applicants should choose an option and give reasons for their choice. Can you give them any advice?

Example 4: No refund cash payment

What is the minimum quantity of banknotes from 100's, 50's, 20's, 10's, and 5's Euro notes and coins of 2 and 1 Euros you would need to be able to pay any sum between 1 and 200 Euros without asking for any change?

Example 5: The journey to the Pirin Mountain

This is one of several such stories published by the Bulgarian writer Elin Pelin who is well known to many generations of Bulgarians for his stories, poems, and novels published in the middle of 20th century. The presentation follows closely a part of a paper containing a good collection of such stories together with some information how these stories were used in the pre-service training of teachers in Bulgaria (Lordanka Gorcheva, Elin Pelin's Story Problems and Modern Mathematics Education, Proceedings of the II Balkan Scientific Conference, "Science, Education and Art in 21st Century", p.190 – 199, Bulgaria, Blagoevgrad, 26-27 September 2008).
Here is the story, told by the story- teller, Old Hand Stanyo.

"Although I am not young, every summer I go hiking. Last summer, for example, I went to the Pirin Mountain. The scenery was magnificent: crystal-clear lakes, lush meadows, rugged cliffs. Unfortunately, I had eaten up the food I had taken with me and I still had a long way to go. I was almost starving when I saw two other hikers coming my way: young fellows, full of joy and energy, named Peter and Alexander. They readily shared their food with me: rolls with bacon. I spread a blanket on the grass, Peter put his 5 rolls on it, and Alexander put his 3 rolls. I told my companions that I would help myself to their food only if they allowed me to pay for it.

We cut the rolls into pieces and each one of us got an equal share. It was delicious! When I left, I gave the fellows all the 16 levs I had.

A few minutes later I heard them call my name, and stopped to figure out what had happened. It appeared that the young men were not able to split my money. Alexander gave Peter 10 levs for his 5 rolls and kept 6 levs for himself. However, Peter felt that he was entitled to more and the two asked me to settle their dispute. We sat on the blanket again, and I told them how to split this money fairly.

Can you, children, tell me how much money either of them took?"

At first glance the distribution of money proposed by Alexander (10 levs to Peter and 6 levs to Alexander) seems correct because the ratio 10 to 6 corresponds to the ratio of the numbers of rolls each one of them put on the blanket (5 to 3). This is, of course, misleading. Since the total number of rolls – 8 -- is not directly divisible by 3. The students have to first figure out how to divide the 8 rolls into 3 equal parts. A natural approach is to cut a roll in 3 equal pieces and give everyone a piece. Proceeding this way 8 times, as is the number of rolls, will ensure that everyone gets an equal number of pieces – 8. Further, for the eight roll pieces he has eaten, Old Hand Stanyo paid 16 levs, thus defining a price of 2 levs per piece. He took seven pieces from Peter and one from Alexander. Hence, Peter '"sold" 7 pieces of rolls to Stanyo and was to receive 7 x 2= 14 levs for them. The remaining two levs had to go to Alexander.

This story was performed by third-graders from 119th School in Sofia, Bulgaria, as a part of a 3-act mathematical play.

Comments

In all the examples given above, the potential to attract students was rooted mainly in the interesting mathematical content. When the content is also combined with measures to involve students into some activity (individually or in teams), the "attraction effect" is much stronger. From this point of view, theatrical activities based on good mathematical context are definitely a viable method to attract students to more active participation in the educational process. In the following examples we present a complete script of a play related to mathematics, which can be used for real practice.

Example 6 A full script example that can be used for practicing Mathematical Theatrical Play

The Pythagorean Theorem

CHARACTERS:
Mr Nikos (Maths Teacher)
Vasily (Foreman)
Kostas (Coffeehouse Keeper)
Builder aides A and B
Students A, B, C
Men at coffee house (silent roles)
Students (in class, extras)

SCENE ONE

Mr Nikos, Kostas, Vasily, customers at coffee house

(At a local coffee house. A few customers chatting, others playing backgammon. Mr Nikos, the High School teacher, steps inside and sits at a table.)

Mr Nikos: (*to the coffee house keeper*) Mr Kostas, can I have a coffee please? (*Unfolds the newspaper on the table and reads. Shortly after, Mr Kostas brings the coffee*) Mr Kostas, do tell me. Does Master Vasily, the foreman, come to the coffee house every day?

Kostas: Indeed he does, Mr Nikos. He'll be here any minute now. You're just in time to see him.

Vasily: (*steps inside and greets everyone*) Good evening folks!

Mr Nikos: Master Vasily, welcome! Won't you come sit with me? There's something I'd like to talk to you about. I'll buy you coffee.

Vasily: I'd be glad to, Teacher! What brings you to our neighborhood?

Mr Nikos: Master Vasily, I noticed today that you brought some tools to the schoolyard and that you also put up a fence in a far corner of the yard.

Vasily: That's right! Did you notice already?
Mr Nikos: Of course I did. So, I wanted to ask, what are you going to build?
Vasily: How did you know we were building something?
Mr Nikos: I sort of heard it through the grapevine and if it is so, I want you to help me with my next class.
Vasily: Anything, Mr Nikos! Always at your service. Well, we've been hired to put up a shed.
Mr Nikos: Great! Let me ask you something. How are you going to carve the shape of the shed on the dirt floor? Are you using any instruments?
Vasily: No, Mr Nikos. It's a simple task. We'll carve it out the old way.
Mr Nikos: Very well. That's exactly what I was hoping for. But tell me, do your workers know how to do it?
Vasily: Bah, I don't think so; they're too young to know.
Mr Nikos: Here's what we're going to do. You tell them to start carving the shape on the dirt floor and in the meantime I'll go there with my students for class. What would be a good time, do you think?
Vasily: Eight o' clock tomorrow morning.
Mr Nikos: Alright, then. We'll be there around 8.15. That will give me enough time to prepare them. Agreed?
Vasily: I'll be waiting for you.

End of Scene One

SCENE TWO

Vasily, Aides A and B, Mr Nikos (high school teacher), Students A, B, C and other students (extras)

(*At the schoolyard where the shed will be put up. The two workers gather their tools and put their gear in place. Planks, a few iron rods, ropes, a measure, nails etc. Master Vasily enters*)

Vasily: (*to his workers*) Hey guys, are we set?
Aide A: Yes, Master Vasily, we're set.
Aide B: Good to go! Just tell us what to do.
Vasily: Alright, listen up. I want you to try and carve the shape of the shed on the dirt floor. We'll build it there, in the corner. Just remember, it's got to be at a three-meter distance from the boundaries.
Aide A: Will do, master Vasily. (*Vasily exits for a while*)
Aide B: (*to the other aide*) Hey, George. Do we know how to carve out a right angle?
Aide A: We could, I guess, if we *had* a right angle – even a small one!
Aide B: But still, how could we have manage such a big right angle using a tiny instrument?
Aide A: So what are we going to do?
Aide B: We'll wait for Master Vasily to come and we'll ask him. It's not a problem to admit we don't know how it's done.
Aide A: True. After all, until now, either the surveyor or the engineer would place the marks using a measuring instrument.
Aide B: Let's just wait for the master.
(*Master Vasily enters with Mr Nikos and his students*)
Vasily: How's it going guys? Are you making any progress?

Aide A: Master Vasily, we haven't done anything; we didn't know how.

Aide B: Yes, before now, the markings were done by either the surveyor or the engineer.

Vasily: Do you mean to say you've never heard of the three-four-five method?

Aide A: No.

Vasily: Alright, listen up. You take a piece of long thin rope and use your measure to tie four successive knots into it. One at the beginning, one at three meters, another one at four meters and the last at five. At the corner which lies at three meters from the boundaries you place a large nail or a peg onto the second knot of your rope and hammer it into the ground.

Aide A: And then?

Vasily: Then you spread the knotted rope along the two sides of the boundaries at three and four meters, place pegs on the knots and connect the two pegs with the five-meter rope. (*The workers do what the foreman tells them to and realize that they have a perfect right angle*)

Aide B: Master Vasily, we did it!

Aide A: Unbelievable!

Mr Nikos: Children, did you see what just happened?

All: Yes, sir.

Student A: How is this possible?

Mr Nikos: Oh, it's possible alright!

Student B: And it works only with three, four, five?

Mr Nikos: No. It works with all multiples of three, four, five.

Student C: And why is that, sir?

Mr Nikos: Well, it is a mathematical theorem. But we'd better discuss this in class. Come on! *(They exit the stage)*

End of Scene Two

SCENE THREE

Mr Nikos (high school teacher), Students A, B, C and extras (students)
(A school class. The children step in with their teacher; they take their seats)

Mr Nikos: So what do you think, guys? Did you like the demonstration of Master Vasily and his workers?

All: Yes, very much!

Student A: But sir, not all of us had a clear view outside; can we repeat it here so that we know for sure how it's done?

Mr Nikos: Of course we can. This is exactly what I had in mind! That's why I've brought everything we're going to need. (*He walks behind his desk and picks up a 60X60 cm piece of plywood, one meter of string, a hammer and nails)* Alright now, let's repeat the measuring process.

Students A&B: (*approaching the teacher's desk*) What are we going to do now, sir?

Mr Nikos: First, you will tie a loop into one end of the string and a second loop at precisely 40 cm from the end. Then, you will pass a nail through each loop.

Student B: (*the kids measure and place the nails*) Done, sir.

Mr Nikos: Hammer the two nails into the wood whilst keeping the string taut more or less in parallel to one side.

Student A: Done!

Mr Nikos: Now, along the same piece of string, at precisely 30 cm, tie a loop then pass a nail through it. Create another loop at 50 cm.

Student B: All set.

Mr Nikos: Pass the end loop through the first nail then pull the other until the string becomes very taut.

Student A: There it is.

Mr Nikos: Now hammer the nail keeping the string well-stretched.

Student B: This is fantastic! It looks like a perfect right triangle!

Mr Nikos: It not only looks like one, it *is* a perfect right triangle! Lift the plywood for everyone to see.

All: Yes, it's incredible!

Mr Nikos: Does anyone know who Pythagoras was? (*students raise their hands*) Go on, Yiannis.

Student A: Yes sir, he was an ancient philosopher.

Mr Nikos: Anyone cares to add something? (*again, students raise their hands*) Yes, Marios.

Student B: Sir, he was also a mathematician.

Mr Nikos: Anything else?

Student C: Yes, sir! He was a musician too!

Mr Nikos: Very good. Does anyone know where Pythagoras hailed from?

Student C: Yes, sir. He hailed from Samos.

Mr Nikos: Indeed. That's why he is known as "Pythagoras of Samos" – for some, one of the Seven Sages of Ancient Greece.

Student C: And where does Pythagoras fit in with this story, sir?

Mr Nikos: You see, when he was young, Pythagoras traveled to Egypt, where at the time a great civilization had developed. So, among the many things he saw there, was the Egyptian rope, the *harpedone.*

Student A: What's that, sir?

Mr Nikos: It was a measuring tool, namely a rope with twelve equally spaced sections marked by tied knots and nails. So using this rope, the *harpedone,* the ancient Egyptians could carve out a right angle, just as we did today. In other words, the same method was used by the Egyptians since 3000 BC, who claimed, 2500 years before Pythagoras, that the angle formed by the 3 and 4 meter sides was in fact right.

Student B: It had a weird name, this Egyptian rope.

Mr Nikos: *Harpedone* is the name of this simple tool; and the *harpedonaptae* were those using it to carve right angles on the dirt floor. It is said that this very method was applied for the construction of the Pyramids. The Indians and the Chinese went on to emulate their example.

Student C: How come this very old story relates to Pythagoras?

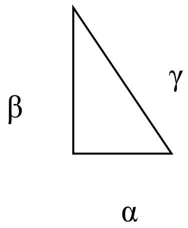
Mr Nikos: Because in the 6^{th} century BC, Pythagoras (569-500 BC) and his students provided a proof of the claim, in other words, that the angle where the three-and-four meter sides meet is a right angle. Therefore, the equation is known in the history of mathematics as the **Pythagorean Theorem.**

All: Unbelievable stuff!

Mr Nikos: So, have you ever heard of the **Pythagorean Theorem?**

Student B: Yes, sir, I think we have.

Mr Nikos: And what does it say, the Pythagorean Theorem? That **"in a right-angled triangle, the sum of the squares of the two vertical sides is equal to the square of the hypotenuse".** (*On the blackboard he draws a right triangle with a, b, and c sides).*



Therefore, if a=3, b=4 and c=5 we shall see that:
3^2=9, 4^2=16 and 5^2 =25, and obviously 9+16=25

Student A: Does this work only with 3, 4, 5?

Mr Nikos: Of course not. The same applies if we double these three numbers into 6, 8 and 10. We can see that their squares are 36, 64 and 100, and that 36+64=100. In fact, it works with any multiples of these numbers because of the validity of this equation: $\mathbf{a^2+b^2=c^2}$

Student B: And how can we actually demonstrate a proof of the equation?

Mr Nikos: Today, proof of the Pythagorean Theorem can be provided in many ways, depending on the students' ages and math knowledge. As for us, we shall demonstrate a rather simple proof.

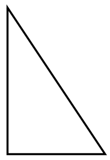
Student C: Sir, can I come up to the blackboard?

Mr Nikos: Yes, why not. Come on up, Constantinos.

Student C: (*stands in front of the blackboard and picks up a piece of chalk*) All ready, sir.

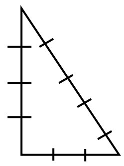
Mr Nikos: Now draw a right angle and try to give it sides that equal 3, 4 and 5 units.

Student C: (*he draws the triangle*) Ready, sir.



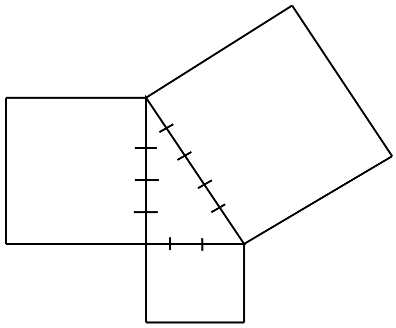
Mr Nikos: Now divide each side into 3, 4, or 5 parts depending on their length.

Student C: (*divides the sides accordingly*) Now?

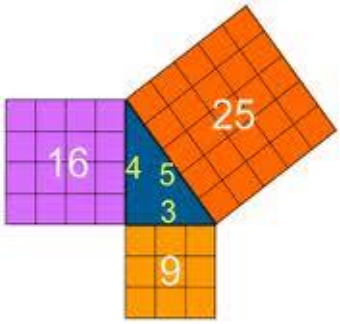


Mr Nikos: Now draw a square on each side.

Student C: (*He draws the squares*) Alright.



Mr Nikos: Now draw parallel lines from the points where you had divided the sides. Do the same along the vertical side of each square.



Student C: (*He draws the lines*) We have created several small squares.
Mr Nikos: Now count those "small squares" as you call them.
Student C: They are 25 on the hypotenuse side and 16 and 9 respectively on the two vertical sides.
Mr Nikos: And what do we see?
All together: (*in unison*) That the 25 small squares of the hypotenuse equal the sum of 16 and 9 squares of the other sides.
Student A: As simple as that?
Mr Nikos: Exactly, as simple as that! Of course, there are several proofs available, depending on the students' age or mathematical knowledge. Do you realize how useful this theorem is, how practical it used to be? And how it is to this day applied in the construction field?
Student B: Yes, sir.
Student C: We should have more lessons like this one!
Student A: Now there's no way we'll ever forget the **Pythagorean Theorem!**
Mr Nikos: (*In the meantime, the bell rings*) Thank you, children. God bless. You may go now.

THE END

*The script is written by Ms Lina Zeniou Papa an actress-director who teaches creative drama (to children and teenagers), affiliated with the THALES Foundation, a partner of Le-MATH project.

4. Evaluation: in-school/in-public

Assessment criteria for the MATHeatre activity in class

I – Mathematical content

The students have approached a mathematical concept studied in class
The students were able to clearly stage the concept
The student have used a theoretical concept and made it comprehensible

II – Theatrical aspect

The students feel at ease/confident in front of their classmates and express themselves appropriately
The students use the space well
The students have respected the given instructions.

III – Creativity of the staging

The students show originality in their performance
The students demonstrate originality in their stage set-up (e.g. decoration, music, projections, etc, ...)

The criteria above can be used according to the education system of each country or school.

Assessment criteria for MATHeatre Competition

The assessment concerns:	**Qualitative levels**		
	Lower	**Intermediate**	**Higher**
Mathematical content			
Relevance of concept(s) discussed			
Ability to make a mathematical theory comprehensible			
Approach used to explain theoretical elements			
Theatrical aspect			
Quality of expression • Delivery: speed of the speech(slow or fast) • Volume : speech is loud enough to be understood. • Articulation: clear pronunciation • Vocabulary : richness of the vocabulary used			
Space management and interaction			
Respect of instructions : - length : 5 minutes to prepare the stage, - 5-12 minutes to play			
Creativity of the staging			
Originality of the appearance and use of costumes			
Use of the electronic back screen of the stage: originality of the projection on the screen and harmony with the play			
Originality and appropriate use of sound effects and music, if needed			

5. ANNEXES

5.1 Le-MATH Manual of Good Practices (visit www.le-math.eu)
5.2 Sample videos of MATHeatre plays (visit www.le-math.eu)
5.3 Lists of scripts from Le-Math Matheatre script competition (visit www.le-math.eu)

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