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Mathematics is everywhere – Connecting with other disciplines

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Abstract
This paper exhibits an analysis of inter - connections between mathematical concepts and concepts from other disciplines. At present every branch of mathematics has a potential for applicability in other fields of mathematics and other disciplines. Each and every discipline contains a compelling essential share with mathematical knowledge or understanding or application. Art and design, Design and technology**,** languages, history, geography, economics, sciences, music, Physical education, Religious education, citizenship- all these fields of human development are interlinking mathematics. All these, have posed a big challenge on the mathematics curricula at all levels of the education systems, teacher preparation and pedagogy. A balanced system between curriculum structure, pedagogical approach and collaboration of teachers training in mathematics and other disciplines is crucial point in context of the global progress. With this, students would see the purpose from the beginning and potentially remain more engaged throughout their lives. The 21st Century mathematics thinking is to more strengthen efforts to bridge the division lines within mathematics, to open up more for other disciplines and to foster the line of inter-discipline research. Therefore, the main challenges will be to explore children's thinking in more depth when bridging home and school mathematics in the context of rich mathematical tasks, as well as to then utilize this knowledge in a meaningful environment for expression of student bureau.

Keywords: Mathematics and Arts, Mathematics and Technology, Mathematics and Sciences, Mathematics and Music, Mathematics and Physical Education, Mathematics and Religious Education

1. Introduction
From its very beginnings, mathematics has been both the most *esoteric* and the most *practical* of human creations. There have been and there are close relations between mathematics and everyday life, the world around us and other sciences.
It wouldn't be out of place to quote the beautiful verses of Mahavıracarya (c. 9th cent.) conveying the efficacy of mathematics. Mahavıracarya, in order to impress upon the importance of the study of mathematics, right at the very beginning of his classical treatise *Ganitasara-sangraha,* expressively puts forth the diverse disciplines in which mathematics finds its application:

लौकिके वैदिके चापि तथा सामयिकेपि यः। व्यापारस्तत्र सर्वत्र सङ्ख्यानमुपयुज्यते॥
कामतन्त्रेऽर्थशास्त्रे च गान्धर्वे नाटकेऽपि वा। सूपशास्त्रे तथा वैद्ये वास्तुविद्यादि वस्तुषु॥
छन्दोलङ्कारकाव्येषु तर्कव्याकरणादिषु। कलागुणेषु सर्वेषु प्रस्तुतं गणितं परम्॥...

बहुभिर्विप्रलापैः किं त्रैलोक्ये सचराचरे। यत्किञ्चिद्वस्तु तत्सर्वं गणितेन विना न हि॥

Fig 1: Ganitasara-sangraha

Whether the dealings have to do with worldly affairs or spiritual matters or religious practices, enumeration is very much involved. In affairs related to love, in economics, in music, in drama, in cooking, in practicing medicine, in the fields like architecture, in using metrics, in [employing] figures of speech, in [composing] literature, in logic, in grammar, in arts, etc, the mathematics [that is going to be discussed] is extremely important. Why keep talking much?

In all the three worlds consisting of living and nonliving entities, whatever be the transaction, it cannot be executed without mathematics! (Ramasubramanian**,** 2012) [5].

Mathematics has been vital to the development of civilization. From ancient to modern times

mathematics has been fundamental to advances in science, engineering, and philosophy.

Developments in modern mathematics have been driven by a number of motivations that can be

categorised into the solution of a difficult problem and the creation of new theory enlarging the

fields of applications of mathematics. Very often the solution of a concrete difficult problem is

based on the creation of a new mathematical theory. While on the other hand creation of a new

mathematical theory may lead to the solution of an old classical problem,

This paper is discussing the relations of mathematics in other disciplines.

2. Objectives

This paper aims to

(i) Find the relations of mathematics in other discipline at school level.

(ii) Focus on the provisions in the curriculum for multidimensional application of mathematics.

(iii) Focus on integrated approach among different disciplines.

3. Methodology

Secondary source e.g. books, journals, internet access are used.

4. Findings

Through mathematical modelling, numerical experiments, analytical studies and other mathematical techniques, mathematics can make enormous contributions to many fields.

Mathematics has to do with human genes, the world of finance and geometric motions.

All these are modelled mathematically, and consequently mathematicians are having a real impact on how those businesses are evolving. Besides, mathematics plays an important role in arts and language also. There are some illustrations from various disciplines in the following.

4.1. Art and design and mathematics

- Art and design use the mathematical ideas of ratio and proportion and different scale of similarity.
- Mathematical ideas of pattern, shape and its transformation are taught in art and design, art and design support the *construction* strand of shape, space and measures in mathematics.
- Art and design also contribute to the development of pupils' problem solving, communication and reasoning.
- There should be references to mathematics in the Curriculum programme of study for art and design. With respect to mathematics and arts, educational activities may include:
- Exploring some mathematical topics in music and visual arts and designing a course for prospective teachers.
- Exploring ways in which different mathematical concepts (e.g., symmetry and asymmetry, patterns and randomness, ratios and proportional reasoning) can be identified in the arts and then focusing on the specific mathematics of those concepts (course for pre service teachers).
- Re-creating the Renaissance in a microcosmic way in the high school classroom gives an opportunity for realising and appreciating the underlying unity of the arts and sciences.

4.2. Biology and mathematics

With the advancement of Biological Science the use of Mathematics is increasing with time. Use of Statistics in various forms are seen in theory and application of Physiology, Reproduction, Heredity, Nutrition, Birth and Death, Growth, Chemical transformation of living body. Many scientists like Darwin, Mendel, and Malthus had solved many problems of Biological Science with the help of different mathematical formulae. Bio- Physics, Bio-Chemistry, Micro- Biology are some branches of Biology where contribution of Mathematics are immensely utilized.

Mathematical models are also emerging in the biological and medical sciences. For example, in physiology, consider the kidney. One million tiny tubes around the kidney, called nephrons, have the task of absorbing salt from the blood into the kidney. They do it through contact with blood vessels by a transport process in which osmotic pressure and filtration play a role. Biologists have identified the body tissues and substances, which are involved in this process, but the precise rules of the process, are only hardly understood. A simple mathematical model of the renal process, shed some light on the formation of urine and on decisions made by the kidney on whether, for example, to excrete a large volume of diluted urine or a small volume of concentrated urine. A more complete model may include Partial Differential Equation, stochastic equations, fluid dynamics, elasticity theory, filtering theory, and control theory, and perhaps other tools. Other topics in physiology where recent mathematical studies have already made some progress include heart dynamics, calcium dynamics, the auditory process, cell adhesion and bio fluids etc. Other areas where mathematics is balanced to make important progress include the growth process in general and embryology in particular, cell signalling, immunology, emerging and re-emerging infectious diseases, and ecological issues such as global phenomena in vegetation, modelling animal grouping and the human brain.

4.3. Design and technology and mathematics

Technology subjects always reinforce pupils' knowledge, understanding and skills in all aspects of measurement, including estimation of measures.

- In *knowledge and understanding of structures*, pupils in calculating loads use method s that reinforces the approach to calculation in the Framework for teaching mathematics.
- In this subjects ratio, proportion and percentages compatible with work in Mathematics are used.
- When pupils are *developing, planning and communicating* their ideas they support the *construction* and *transformations* strands of shape, space and measures. They also use scales and scale factors.
- different strands of handling data applicable to technology teaching, in

- Particular when pupils are *evaluating processes and products are used.*
- There are links between using and applying mathematics and the problem solving elements of technology.
- For accuracy of measurements, use of decimal places and significant figures, and use of units and their abbreviations are used.

4.4. Economics and mathematics

Matrices are tools for linear models of production in economics. The concept of derivatives, algebraic functions and their graphical representations with their formal aspects in relation to economic interpretations are used. Finance is very mathematical; it has to do with derivatives, risk management, portfolio management and stock options. The main idea is to build bridges, not only between maths and economics, but also between different settings and stakes within maths. It is essential that students be able to interpret a result in graphical, algebraic or formal settings and to make connections between these settings. Giinter Ossimitz (1988) pointed out that mathematics in economic and management sciences is mostly descriptive mathematics or elementary arithmetic. He emphasized that the fundamental act of mathematization in this field is measurement, through which qualitative stuff is transformed into quantitative structures. In his final thesis he argued that the relation of mathematics to economics is comparable to that of chemistry to medicine.

4.5. Geography and mathematics

- Teaching within geography support work on coordinates and measures.
- Different parts of the handling data cycle – state problem, identify and collect data,
- Analyse and represent data, interpret results – relate directly to work in geography.
- Graphs and charts are used in geography.
- Geographical Information Systems (GIS) technology is an increasingly useful and popular way of recognizing and studying relationships in our environment by analyzing spatial patterns. This is becoming a standard research tool among environmental professionals and in graduate institutions. Students may use GIS to examine the spatial arrangement of gopher tortoise burrows and grazing areas and determine how this arrangement relates to topography and vegetation. As in the case of other wildlife, increased human population and traffic may directly or indirectly impact not only the population of tortoises, but also where they burrow and graze. Does their development support the progression outlined in the yearly teaching programmes for mathematics? Do our labelling conventions for graphs match those of the mathematics department?
- In many ways our work on thinking skills in geography could contribute to the development of using and applying mathematics. There should be opportunities for joint work with the mathematics department. We would identity the units which offer greatest potential for joint working. There should be ICT use in this work.

4.6. History and mathematics

Different elements of the number and calculation strands of mathematics feature in teaching history. We should be familiar with the approach to calculation in the framework for teaching mathematics. Our teaching should support this approach.

- Various parts of the handling data cycle – state problem, identify and collect data, analyse and represent data, interpret results – relate directly to work in history.
- Graphs and charts are used in history. Does their development support the
- Progression outlined in the yearly teaching programmes for mathematics? Do our
- Labelling conventions for graphs match those of the mathematics department?
- In many ways our thinking skills in history could contribute to the development of using and applying mathematics.

4.7. ICT and mathematics

The references to ICT for teaching mathematics represent appropriate application of ICT in supporting pupils' learning.

- Various general-purpose ICT packages are in use to support pupils' mathematical Development. There should some mathematics packages to be used in ICT. They should include Logo, graph plotting and dynamic geometry software in the yearly teaching programmes.
- Other subjects do have access to appropriate ICT systems for supporting pupils' mathematical development.

4.8. Languages and mathematics

Specific knowledge, skills and techniques

- at word level
- at sentence level
- at text level
- can be developed in English, Bengali, Hindi, Arabic/language lessons that will help pupils to:
- use mathematical vocabulary correctly,
- explain and justify their methods and conclusions,
- interpret and discuss results,
- solve word problems,
- Communicate orally and on paper the results of a statistical enquiry or other in-depth piece of mathematics.
- To some extent mathematics do support to the development of words involved in reasoning and proof (for example, 'if … then', 'therefore', 'it follows that', etc.).
- To some extent mathematics does work on interpreting information/being a critical reader contribute to the development of mathematics (for example, handling data presented in charts, graphs and diagrams).
- Again, the skills developed in language lessons might enhance pupils' capacities to solve problems, to reason and justify, and to evaluate their work in mathematics.

4.9. Material Science and Mathematics

Material Science is concerned with the synthesis and manufacture of new materials/ chemicals, the modification of materials, the understanding and prediction of material properties, and the evolution and control of these properties over a time period. Today it is a vast growing body of knowledge based on physical sciences, engineering, and

mathematics. For example, mathematical models are emerging quite reliable in the synthesis and manufacture of polymers. Some of these models are based on statistics or statistical mechanics and others are based on a diffusion equation in finite or infinite dimensional spaces. Another example is the study of composites. Motor companies, for example, are working with composites of aluminium and silicon-carbon grains, which provide lightweight alternative to steel. Fluid with magnetic particles or electrically charged particles will enhance the effects of brake fluid and shock absorbers in the car. Over the last decade, mathematicians have developed new tools in functional analysis, PDE, and numerical analysis, by which they have been able to estimate or compute the effective properties of composites. But the list of new composites is ever increasing and new materials are constantly being developed. These will continue to need mathematical input. As another example, data collected for chemistry projects on fertilizer application could be used to study the leaching of nitrogen and phosphates and nitrophication of local water bodies.

4.10. Mathematics within mathematics

.This *is intended t*o be used within a department meeting before the whole-school annual routine *program on mathematics across the curriculum.*

- There should be opportunities to work with other departments.
- Which parts of mathematics will have the most applications in other subjects? In which year?
- What needs to be done to prepare the ground before such work can take place?
- What would be the anticipated benefits for pupils?
- Where should we give priority?

Number System, Fundamental arithmetic, Basic algebra, functional mensuration, practical geometry, sensible probability and down-to-earth statistics be arranged in ordered sequence as per ability of the students and needs of the society.

4.11. Music and mathematics

Music makes significant use of symbolic representation, as does mathematics.

There should some space of the similarities in the ways symbols are interpreted in both subjects.

- How can work on equivalent fractions enhance pupils' understanding of the relative values of notes?
- There are links between mathematical sequences and those found in music, such as rhythm patterns. Counting to a regular rhythm often forms part of a pupil's earlier mathematical education; This can be used to enhance pupils' understanding of rhythm.
- Rhythm patterns, represented either symbolically or numerically, can be seen to have parallels in mathematical sequences.
- Pupils' knowledge of time and speed can enhance their understanding of musical time, when considering technical issues such as beats per second and the differences between certain types of music, for example music from around the world, pop, techno, and so on.
- The study of pattern in musical forms such as ABA, AABA, ABAB (leading to sonata and symphonic form) is enhanced by pupils' understanding of repeating patterns in mathematics.
- When looking at shapes in written music (such as high/low, rising/falling, ascending/descending), comparisons can be made with pupils' work on graphs.
- Music can also contribute to the development of pupils' skills in organisation, logical thought, problem solving, collaborative working, listening to and sharing opinions.

4.12. Physical education and mathematics

There are many links (for example, in gymnastics or dance) building upon ideas of pattern, movement and symmetry developed in mathematics.

- The teaching of physical activities develops pupils' awareness of time, distance and speed.
- Knowledge of map references, compass bearings and estimates of distances travelled developed in planning and carrying out outdoor activities.
- In many ways pupils do gather and use performance data:
  - In general fitness work,
  - In specialised work such as athletic activities.

This work also do support to the handling data strand of mathematics.

Mathematics can be used to support pupils' interpretations of performance data.

- When differences in readings from manual and electronic data-logging equipment are discussed, reference should be made to statistical terms such as the mean, mode and median that might be appropriate for measuring performance in a range of physical activities.
- Pupils use problem solving, communication and reasoning in physical activities.

4.13. Physics and mathematics

One interesting bridge between mathematics and physics in secondary education concerns the relation between vectors and forces. In mathematics, very few examples are resented. Vectors remains essentially a tool for geometry and the teaching tends to algebraic properties. On the other hand vectors are a model of the concept of force in physics.

Another part of physics relates to translatory and rotating movements and translation and rotation. It is well known that geometrical transformation is cognitively attached to dynamical representation. This representation of a geometrical rotation is coherent with the concept of rotating movements in physics.

4.14. Science and mathematics

Being the language of sciences, mathematics has a great potential to make tremendous contributions to the other sciences.

- Different aspects of handling data are developed during science lessons. ICT devices are used in this work (for example, sensors, spreadsheets, computer graph packages, calculators, graphical calculators). This work does enhance pupils' mathematical development.
- There should be some common platform to be agreed with the mathematics department when and how to introduce pupils to continuous data, as distinct from discrete data.
- Science helps to develop pupils' understanding of numbers in context, particularly large numbers,

fractions and decimals, indices, ratios and proportions, and the relationships between different metric units.
- To some extent science teaching does support the methods and approaches relating to aspects of calculation that are developed through the mathematics teaching programmes.
- The teaching and interpretation of formulae and graphs do support the expectations in mathematics. There should be some common agreement with mathematics how graphs should be labelled and presented. The progression in graphical work in science must have to support its development in mathematics. ICT could be used (graph plotters, graphical calculators) to support this work.
- Needs of science might be compatible to some extent to the approach to the manipulation of algebraic expressions and solution of equations in the teaching mathematics.
- Work in science link with using and applying mathematics in our school curriculum.

4.15. Religious education, citizenship and mathematics

When discussing numbers (for example, in populations), time differences, fractions, percentages and proportions, teaching is built upon the expectations set out in the number strand of teaching programmes for mathematics.
- Many work involves handling and interpreting data as a means of enabling pupils to become better informed citizens. Some elements of the handling data cycle – state problem, identify and collect data, analyse and represent data, interpret results – are used most. ICT is used in this regard.
- teaching might employ a range of graphs and charts in line with expectations in the mathematics teaching programmes. (It is worth looking at the examples of statistics from these subjects.)
- there are opportunities to make links with mathematical work on maps, scales and distances
- All pupils from different cultures should be introduced to mathematics.
- pupils do use mathematical knowledge and skills when they have to explore the ideas of probability, risk and chance.
- To monitor correct use of mathematical vocabulary where appropriate is the duty of all mathematics teacher and learner.
- When exploring evidence, pupils must be given opportunities to develop their competence in problem solving, communicating and reasoning.

5. Conclusion

The teaching of mathematics is a subject to a social pressure that requires more applications and raises issues about modelling. The outside world forces mathematics to come out of its ivory power. This is true for all levels of education in any context. It is more essential for students whose major interest is outside mathematics. It is not possible anymore for mathematicians to remain isolated, away from applications, in a position of superiority. This is the best thing that could have happened to mathematics, which needs to become more visible. Using a context issued from another discipline is not only a question of psychological motivation, but also an epistemological challenge. Indeed using an example from another discipline is not only a (fashionable) way to motivate students, but it is also a way to present a richer context where issues on the meaning of mathematics will automatically addressed and questioned. This is not just an abdication of supremacy, but a humble recognition of the power of mathematics as a provider of models to other disciplines which has always been an essential part of its history. The context of teaching (stressing students' profile, curricular demands and institutional restrictions) seemed to be determinant for *not* including topics of other subjects in the teaching of mathematics. Responses stressing "lack of material" and "discomfort with science" together with "fear of giving misleading information" should be considered as a call for attention with regard to future in order to play an assisting role for teachers. But certainly the most important thing to do is still: *To intensify the efforts to integrate applications to other subjects into "standard" everyday mathematics teaching*, by means of curricula, of textbooks and materials for learners and teachers, by pre-service and especially by in-service teacher training.

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