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Aesthetic dimension in mathematics at school level

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Abstract
Focusing on humanistic mathematics, this paper seeks to provide a stronger rationale for the importance and relevance of aesthetic considerations in mathematics. Mathematics has its own language and it is universal. Precision, exactness, transparency, straightforwardness, unambiguous, simplicity, symmetry, uniqueness, peacefulness are some of its characteristics. An aesthetic sense always exists in all its patterns, numbers, forms, geometrical objects, algorithms, chance and change, proofs, identities, explanation, and interpretation. In all wonderful creation of the world there is an interweave involvement of the gift of mathematics. A close relation between truth and beauty continue to exist for all time all over the place in the world. Every truth has its own beauty which could only be felt and vice versa. Mathematics education develops a strong base of moral values in the form of integrity, patience, respect to others opinion, discipline, punctuality, truthfulness, socialization, affinity to beauty and brilliance etc. Mathematics is in everywhere either in direct, indirect or hidden form.

Keywords: aesthetic sense, mathematics, school level

1. Introduction
The word ‘Mathematics’ has different meaning to different people. People perceive mathematics according to their own experience and these experiences differ from person to person. Merely being a study of arithmetic, algebra and geometry mathematics today is a diverse discipline that deals with measurement, data analysis, observations from various fields of knowledge, inductive generalizations, proofs, logical deductions and mathematical modelling of natural phenomenon, of human behaviour and of social system.
In ‘Essays in Humanistic Mathematics’, Alvin M. White describes the humanistic dimension of mathematics as including both: an appreciation of the role of intuition in understanding and creating concepts" and an understanding of the value judgments implied in the growth of any discipline [...] what is investigated, how it is investigated, or why it is investigated" (vii). Both these aspects relate strongly to the mathematical aesthetic in two ways. First, in writing about the importance of the value judgments made in the discipline, Alvin M. White points to the axiological dimension of the philosophy of mathematics, which include both aesthetic and ethical questions of what is beautiful or ugly, good or bad, and why. Second, in pointing to the role of intuition in understanding and creating concepts, Mathematicians such as G.H. Hardy attempted to over criteria by which one could judge aesthetic merit, taking a rather objective view that aesthetic merit was independent of the observer and intrinsic to the mathematical product itself {a view that was mainstream in the philosophy of arts even at the turn of the last century (in the work, for example, of Roger Fry and Cleve Bell). In ‘A Mathematician's Apology’, Hardy emphasizes criteria such as depth and significance, as well as purely aesthetic qualities such as unexpectedness, inevitability and economy. He famously claimed that the mathematician's patterns, like the painter's or the poet's, must be beautiful; the ideas, like the colours or the words must fit together in a harmonious way" and that there is no permanent place in this world for ugly mathematics." (p.85). In a similar vein, in terms of objective criteria of finished products, King [24], in an attempt to distinguish good" mathematics from bad" (to save the world from bad" mathematics?) proposed two definitive criteria: the principle of minimal completeness and the principle of maximal applicability.

2. Objectives
1. To focus the disciplinary values of mathematics.
2. To make an aesthetic sense of mathematics among students and teacher
3. To reduce the fear in mathematics among students.
4. To explore the relation of beauty and truth among students
5. To inculcate moral values and universality of mathematics.

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

4. Disciplinary Values in the Nature of Mathematics
According to NCF – 2005, the main goal of mathematics education in school is mathematization of child’s thought process. There are two aims of school mathematics – the narrow aim and higher aim.
The narrow aim of school mathematics is to develop ‘useful’ capabilities, particularly those relating to numeracy- numbers, number operations, measurements, decimal and percentage. The higher aim is to develop child’s resources to think and reason mathematically, to pursue assumptions to their logical conclusions and to handle –abstraction.
The result of mathematics is exact, real and pure. It explores natural truth in a beautiful mathematical form. Mankind of the world appreciate the reality integrity of the fact through simple equation or formula and wonder by its truthfulness, straightforward, uncomplicated piece of information. Mathematical proofs have attractiveness and loveliness of their own. In mathematics an orderly elegant proof uses

minimum number of assumptions or already established results, it is based on new and original insights and can be adopted in solving problems of similar kind.

All the natural events follow definite rules which can be expressed by mathematical laws and equation. Scientists and Mathematicians enjoyed their working pleasure with aesthetic pattern, method and language of mathematics. As for example Newton's laws of gravitational force expressed its truth by the famous equation:

$$F = \frac{Gm_1 m_2}{R^2} \quad \ldots [1]$$

Where

G = Gravitational Constant

M_1 = mass of one body

M_2 = mass of second body

R = distance between the centre of the two bodies

Appreciating the language of mathematics, a great scientist Galileo said "mathematics is the language with which the God wrote the Universe".

Beauties in mathematical results reveal that it derives a result from apparently unrelated results. An example for that is Euler's identity: $e^{i\pi}+1=0$, where e is the Euler's number, the base of natural logarithms, I is the complex number whose square is -1, pie is the ratio of the circumference of a circle to its diameter. All the five quantities which seem to be completely unrelated are closely related by this identity. In this equality each of the basic mathematical operations of addition, multiplication and exponentiation occur exactly once each. Also, the identity gives a relation between the additive identity 0, the multiplicative identity 1, the number pie which is used in trigonometry, Euclidean geometry and analytical mathematics, the number e, the base of natural logarithms and the number I, the imaginary unit of the complex numbers whose study shows the way to deeper insights into many areas of algebra and integral calculus. Where such amazing findings would be found?

Mathematics itself develops powers of reasoning, rationale and thinking. It helps learners to develop kinds of exercise self-control, accuracy, simplicity, originality, reasoning and other outcome of these characteristics like obedience, concentration, truthfulness, sincerity genuineness etc. Teachers should encourage them to flourish these qualities, values through different activities inside and outside classroom or school.

Mathematics knowledge imparted should cultivate values such as development of concentration, the power of expression, attitude of discovery, self-reliance, economical living and the quality of hard work as all these qualities are essential for a human being to survive in the world.

It is said, 'Mathematics is the mirror of civilization' It helps an individual to overtime difficulties in the ways of his / her progress. The prosperity of an individual and her cultural advancement have depended significant progression in mathematics. Contributions of mathematics to the advancement of modern civilizations can't be undermined to its development to the evolution of a variety of occupations such as agriculture, engineering, surveying, medicine, trade, industry, navigation, road- rail building, banking, e- banking, telecommunications, space researcher etc. Mathematics has enabled students to understand the role of mathematics in fine arts and in beautifying surroundings of world. Again knowledge of time and speed enhance the 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.

5. Relating Learning of Mathematics to Learners Real Life Situation

Emphasis should be given to 'learning for living' instead of 'living for learning' and for this purpose the first and foremost duty of a mathematics teacher is to help the child build appropriate meaning of mathematics as a subject of learning as well as an effective instrument to deal with social, economic and psychological problems frequently encountered in daily life. Keys to Success are entitled Organizing the Classroom, Organizing Instruction, and Organizing the Content. In these context teachers shared experiences will be such that all students should:

1. Demonstrate confidence as mathematical thinkers, believing that they can learn mathematics and can achieve high standards in mathematics, and accepting responsibility for their own learning of mathematics.
2. Recognize the power that comes from understanding and doing mathematics.
3. Develop and maintain a positive disposition to mathematics and to mathematical activity
4. Participate actively in mathematical activity and discussion, freely exchanging ideas and problem-solving strategies with their classmates and teachers, and taking intellectual risks and defending positions without fear of being incorrect.
5. Work cooperatively with other students on mathematical activities, actively sharing, listening, and reflecting during group discussions, and giving and receiving constructive criticism.

6. Coexistence of Beauty and truth in mathematics

Bertrand Russell, one of the greatest mathematician and Philosopher describe the beauty of Mathematics as "Mathematics rightly viewed, possesses not only truth, but supreme beauty – a beauty cold and austere, like that of a sculpture, without appeal to any part of our weaker nature, without gorgeous trappings of paintings or music, yet sublimely pure, and capable of a stern perfection such as only the greatest art can show. The true spirit of delight, the exaltation, the sense of being more than Man, which is a touch stone of the highest excellence, is to be found in Mathematics as purely as poetry."

Wolfgang Krull's claims, "Mathematicians are not concerned merely with ending and proving theorems, they also want to arrange and assemble the theorems so that they appear not only correct but evident and compelling. Such a goal, I feel, is aesthetic rather than epistemological". [26, p.49]

Mathematics is one place where precisions and exactness are always weaving. Students should encourage to think, to solve, to formulate; to make conjectures in many different ways, but for one particular situation or problem or phenomena one correct and unique answer exists. Many ways meet in a single destination which is absolutely true. Truth always spread the rays of lights to the darkness. Beauty of every object is full of spirit of truth. G.H. Hardy in his renowned book 'A

Mathematician's Apology' demonstrates that mathematics through precise is beloved about beauty. He gives two examples to illustrate that beauty and precision coexist in mathematics. One example is 'Showing that there is no rational whose square is 2' and the other 'Showing that there is no largest prime number'. Both the proofs are simple, easily graspable, but are precise and stir the soul with pleasant surprise. In mathematics simplicity overcome complexity, symmetry prevail asymmetry, order win through disorder, harmony wins disharmony, dispute and disagreement. An analysis of the aesthetic experience directs us to believe that aesthetic feelings are because of an unusual extent of congenial inter- relationship within the object. These elements of congenial inter- relationship or order are similarly, contrast, equality, symmetry, uniformity, balance, congruency, adequacy and sequencing. These elements have constructive consequence on the aesthetic degree. But the complexity of the objects creates it more knotty to feel the aesthetics of the objects. Truly George David Birkhoff gave a formula to measure aesthetic feelings by

$$M\alpha \frac{O}{C} \quad \ldots [2]$$

Where
(i) C is the Complexity of the object
(ii) M is the aesthetic measure or feeling value and
(iii) O is the harmony, symmetry or order of the object
In the words of famous mathematician Paul Erdos, "Nobody can explain you the beauty of mathematics, you have to experience it yourself."

7. Universality of Mathematics

The nature of mathematics is universal. For example, any figure of a triangle induces the same properties all over the world. There is no disparity of explanation or interpretation of any concept or theory or notion among different mathematician of different countries. Every teacher should be pleased about to transmit the universal nature of mathematics with illustrating various examples and that mathematics has its origin in daily life needs and happenings in the world around us.

8. Promotion of moral values through mathematics education

Le Lionnais [28] and Poincar, Rota [42] draws attention to the way in which aesthetic descriptors used by mathematicians. "Mathematical beauty is the expression, mathematicians have invented in order to obliquely admit the phenomenon of enlightenment while avoiding acknowledgement of the fuzziness of this phenomenon. [...] This copout is one step in a cherished activity of mathematicians, that of building a perfect world immune to the messiness of the ordinary world, a world where what we think should be true turns out to be true, a world that is free from the disappointments, the ambiguities, and the failures of that other world in which we live." (pp.132-133; italics in original)
Through the study of mathematics scientific attitudes develop. The pupil respect the opinions of others, accepts errors without hesitation, keeps an open mind and develops the habit of logical thinking, develops appreciation for its brevity, preciseness, abstractness, structure and its deductive nature. Through progress of these qualities moral values like integrity, truthfulness, acceptance of responsibilities, co- operations with others, patience to others thought, reliability, consistency and trustworthiness are strengthen. Teacher should engage students in group activities, project work, peer evaluation, laboratory experiment, field trip, organizing quiz, debate and seminars with outside resource persons, mathematics cub etc. Besides those, teacher may illustrate some problem with inner hidden moral values Few examples:

1. A class of 20 boys and 15 girls is divided into n groups so that each group has *x* boys and *y* girls. Find *x*, *y*, *z* and *n*. What values are preferred in a class?
   Solution: H.C.F. of 20 and 15 = 5.
   So the 5 students are in each group, so
   $$n = \frac{(20+15)}{5} = 7$$
   Hence, *x*= 4, *y*=3 and *n*= 7.
   Values:
   - Promote co education.
   - Promote and help to educate girl child
   - Role of activity in groups
   - Increasing healthy and friendly environment at school level.
2. Speed of boat in downstream is 8 km/ hr whereas in upstream speed is 2 km/ hr. Find the time taken by boat in 16 km downstream and 8 km upstream. What should be learning in real life?
   Solution: Time taken by boat in 16 km downstream
   $$= \frac{16}{8} hr = 2 \text{ hr}.$$
   Time taken by boat in 8 km upstream
   $$= \frac{8}{2} hr = 4 hr.$$
   Values:
   - In opposite condition we should be very patient full and careful
   - We should try to avoid opposite conditions because in opposite condition output is very low but yes if we needed should face it carefully.
3. A teacher shows circles of different radii to all students of a class of 35 students and asked what you observed and learned from it.
   Solution: Circles of different radii are not congruent but always similar.
   Values:
   - We may have different ideas, different thoughts and different languages but we all are similar ass human being.
4. What are the basic trigonometric identities? Also explain the values of identities.
   Solution: $H^2 = P^2 + B^2$ (by Pythagoras theorem) … [3]
   If we divide both sides by H^2, P^2 and B^2 respectively then we get,
   $$sin^2\theta + cos^2\theta = 1 \quad \ldots [4]$$
   Similarly, $1 + tan^2\theta = sec^2\theta$ … [5]

And $1 + cot^2\theta = cosec^2\theta$ … [6]

So these are three basic trigonometric identities.

Values:

- Identities are those which are always correct for any value of variable, so in the same way in life we should be always truthful in any condition of any variable

In this way, mathematics always commits moral support to all, if properly rationalize. William Thurston [52] draws attention to the value of socially-shared understanding: "We are not trying to meet some abstract production quota of definitions, theorems and proofs. The measure of our success is whether what we do enables people to understand and think more clearly and effectively about mathematics." (p.3)

9. Conclusion

To conclude the author would like to draw the attention by pointing to a number of questions that emerge in considering the aesthetic dimension of student learning and the presence of aesthetics in theoretical developments in mathematics education. These questions span a wide conception of aesthetics that include the aesthetic as a theme in human experience (as a way that human organize and derive meaning from everyday situations) and the aesthetic as a field of study, which includes the nature of perceptually interesting aspects of phenomena and artefacts.

1 How might (and should) aesthetic considerations in mathematics differ from those in school mathematics?
2 Can aesthetic sensibility be taught? If so, how?
3 How do theories of embodied cognition relate to aesthetic perception?
4 How can mathematicians help educators to gain entry into the aesthetic values that guide their work?

Finally, when we realise everything about its focused dimension, we could say joyfully

"Where there is truth there is beauty and where there is beauty there is Mathematics"

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