Using Multiple Intelligence Theory in the Mathematics Classroom

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Abstract

Gardner's theory of Multiple Intelligences (MI) states that people learn through a combination of eight intelligences rather than one intelligence as was originally believed. Furthermore, each person has several dominant intelligences through which he/she learns better and more quickly. Two applications which use multiple intelligences in teaching concepts in college level mathematics courses are described. Anecdotal evidence suggests that students have better long-term comprehension when multiple intelligence theory is used in the presentation of concepts. Finally, the need for formal assessment of the outcome of using MI theory is discussed.

Introduction

The purpose of this paper is to introduce the theory of multiple intelligences and show how it can be used in the classroom. The authors had been using learning style theories in developing applications in the mathematics and physics classrooms in an effort to maximize the outcome for students with very diverse backgrounds and natural abilities. Teaching an extremely heterogeneous group of students presents this challenge. How does one impact the long-term comprehension of concepts in a classroom where the students' natural abilities are so varied? It became clear that multiple intelligence theory, developed by Howard Gardner, provided a definitive, yet broad framework for developing curricula which could be used to better service this group of students.

Using MI theory, we have experimented with a number of presentations techniques in the classroom. Two examples, physical models of mathematical concepts and visual models of algebraic concepts are presented in this paper. Initial student reactions have been positive and indicate increased comprehension as a result of using these techniques.

The historical background of how MI theory evolved as an educational philosophy will be described. Each of the eight types of intelligences are explained and two applications of how MI theory has been used in the mathematics classroom are presented. The results of using MI theory and suggestions for using this theory in developing curriculum are discussed throughout the paper.

Multiple Intelligences

According to Multiple Intelligence (MI) theory, individuals possess a set of eight intellectual competencies by which they learn, as opposed to one general intelligence. The eight intelligences are verbal/linguistic, logical/mathematical, spatial, bodily/kinesthetic, musical, interpersonal, intrapersonal, and naturalistic. In any given individual some of these intelligences may be stronger than others.

In a classroom, the areas of strengths are different for each student. Therefore, the goal of helping a diverse group of students reach their maximum learning potential presents two major challenges to the instructor. First, it is imperative to identify one's own dominant intelligence areas and to realize that not all students in a class possess those same strengths. The second challenge is to develop classroom presentations which use a variety of techniques that are compatible with the students' individual intellectual competencies. This is critical for optimal learning.

Historical Background

The history of intelligence testing started in 1904 when the Minister of Public Instruction in Paris asked French psychologist Alfred Binet and his colleagues to develop a means of determining which primary school students were at risk for failure[1]. The first "IQ" test was developed and similar tests are still in use today. These tests assess mathematical, logical, and word usage skills to determine intelligence. It wasn't until 1983 that Howard Gardner, a Harvard psychologist, challenged the concept of a single measure of intelligence. He proposed a broader definition of intelligence which included the existence of at least seven basic intelligences, all of which would focus on the capacity for problem solving and fashioning products in a context-rich and naturalistic setting. MI theory was very controversial in the psychology arena; however it attracted considerable attention from the educational community.

Eight Multiple Intelligences

Gardner currently uses eight basic intelligences to define the broad range of abilities that humans possess in a pragmatic manner. A description of each of the intelligences and examples of people who exemplify each intelligence are presented here as background for the application of the MI theory. The descriptions and examples of people are taken largely from two of Howard Gardner's book, *Frames of Mind, The Theory of Multiple Intelligences*[2] and *Multiple Intelligences*, *The Theory in Practice*[3] , in conjunction with Thomas Armstrong's book, *Multiple Intelligences In The Classroom*[1]. References to how the intelligences are used, or could be used in the mathematics classroom are from the authors' personal experiences.

1. Verbal/Linguistic Intelligence:

- the ability to use language to convince other individuals of a course of action,
- the capacity to use mnemonics to help one remember information,
- the ability to use oral and written language in explanations, and
- the ability to use language to analyze how language works.

This intelligence is personified by poet T.S. Elliot. Every word in his poetry is analyzed for purpose, clarity, and consistency.

Verbal intelligence is probably the intelligence which is most widely used in the traditional lecture format. This makes a very big assumption about the type of intelligence of the students in our classes.

2. Logical/Mathematical Intelligence:

- sensitivity to logical patterns and relationships, statements and propositions (if-then, cause-effect), functions, and other related abstractions, and
- the ability to skillfully handle long chains of reasoning.

Mathematical intelligence is personified by scientists, such as Barbara McClintock who won the Nobel Prize in medicine for her work in microbiology in 1983. The gifted scientist works with many variables and hypotheses at once and rapidly evaluates, accepts or rejects, and makes conclusions, often constructing a solution to a problem before it is articulated. In other words, it is non-verbal and non-visual.

Strong mathematical intelligence is often assumed in the engineering, mathematics, and physics classroom and lectures are based on this strength. Realize that this is not the only intelligence that we could utilize to enhance students long-term comprehension of concepts.

3. Visual/Spatial Intelligence:

- the ability to perceive the visual-spatial world accurately and to perform transformations upon those perceptions,
- sensitivity to color, line, shape, form, space, and the relationships that exist between these elements, and
- the capacity to visualize, to graphically represent visual or spatial ideas, and to orient oneself in the spatial matrix.

Visual intelligence can be seen in the works of artists, architects, engineers, hunters, and interior decorators, among others. Lectures which rely on one's ability to transform figures in one's mind, which have been drawn on the board, require the use of visual intelligence.

4. Bodily-Kinesthetic Intelligence:

- the ability to use one's body in highly differentiated and skilled ways,
- expertise in using one's body to express ideas and feelings,
- the facility of using one's hands to produce or transform things, and
- the capacity to work skillfully with objects, using both fine motor movements and gross motor movements of the body.

An extraordinary mime performance by the French artist Marcel Marceau or the performance of amazing physical feats by Michael Jordan exemplify the use of bodily intelligence. While this intelligence is often not used in the classroom, there is the potential to describe mathematical and physical concepts using bodily intelligence. Dance, for example, can be used to mimic mathematical patterns or trends in a function. Physically creating an object described by an equation uses this intelligence.

5. Musical Intelligence:

- the capacity to perceive, discriminate, transform, and express musical forms, and
- sensitivity to rhythm, pitch or melody, and timbre or tone color of a musical piece.

Musical intelligence is exemplified by any number of composers, such as Aaron Copland whose perspective is both global/intuitive and analytical/technical. Igor Stravinsky points out that "composing is doing, not thinking; it is accomplished naturally". Musical intelligence is often overlooked in the traditional classroom. However, this intelligence can be used constructively to interpret some mathematical and physical concepts. Students, in our classes and those of our colleagues, with strong musical intelligence have used analogies to musical concepts to describe mathematical concepts when they were prompted to think in this manner.

6. Interpersonal Intelligence:

- the ability to perceive and make distinctions in the moods, intentions, motivations, and feelings of other people,
- sensitivity to facial expressions, voice, and gestures,
- the capacity for discriminating among many different kinds of interpersonal cues, and
- the ability to respond effectively to those cues in a pragmatic way.

Highly developed interpersonal intelligence can be seen in political and religious leaders such as Mahatma Gandhi and in skilled parents, educators, and counselors. Applying MI theory in the classroom, in fact, requires using interpersonal intelligence to determine how to best relate to a broad spectrum of student intelligences. The student with strong interpersonal intelligence generally needs to connect the information or concept being taught with something having to do with people.

7. Intrapersonal Intelligence:

- the ability to act based on self- knowledge,
- sensitivity to one's strengths and weaknesses, inner moods, intentions, motivations, temperaments, and desires, and
- the capacity for self-discipline, self-understanding, and self-esteem.

Intrapersonal intelligence can be seen in the writings of novelists like Proust who write introspectively. Unfortunately however, it is not a highly valued intelligence in Western culture. Self directed study could be used extensively in education if the use of intrapersonal intelligence was cultivated and rewarded.

8. Naturalist Intelligence:

- the ability to recognize fine distinctions and patterns in the natural world, and
- the capacity to use this ability productively.

Naturalist intelligence was recently added to Gardner's original seven intelligences. This intelligence is embodied by people like Charles Darwin who can comprehend definite distinctions and patterns in the natural world which might not be recognized even by a person with strong mathematical or visual intelligences.

Applications

The following two applications use a variety of the intelligences. These applications have both been tested with several different classes. The student satisfaction and long-term comprehension increased over previous classes which were taught in a more traditional, verbal/mathematical, manner.

1. Finding the volume of a solid body

In calculus, the volume of a solid body which is formed by rotating an area around an axis can be found using the method of disks, if the bounding curves of the area are known functions. The explanation of the process used to find the volume can take on many forms. Explanations which use the visual, bodily, interpersonal, intrapersonal, and verbal intelligences are described.

Students with highly developed **visual intelligence** or **mathematical intelligence** will be able to understand the procedure for finding the volume of a solid body rotated about an axis, given this explanation:

- Imagine the parabolic area in Figure 1, which is bounded by $\mathbf{y = 9 - x^2}$ **, y = 0, and x = 0**, being rotated about the y-axis to form a parabloid, whose volume is $\mathbf{V_P}$.
- Imagine that this parabloid is made up of a stack of thin, circular disks which are progressively smaller as you go from the bottom of the parabloid to the top.
- Given that the volume of a thin, circular disk ($\mathbf{V_d}$) which is a right circular cylinder is the area of the circle with radius, **r**, times the height, ***h,*** of the disk, or $\mathbf{V_d} = (\pi \cdot r^2)\, h$, then the volume of the parabloid is the sum of the volume of all of the disks from **y = 0 to y = 9**, or

$$\mathbf{V_d} = \sum_0^9 \pi r r^2 h$$

- Knowing that in calculus the integral sign, $\int$, is the equivalent of summation, and that a very small change in a variable is represented by the differential of that variable (***dy*** for example represents the height of a disk in this example) then the volume of the parabloid can be represented as:

$$\int_0^9 (\pi \cdot r^2) \cdot dy = \int_0^9 \pi \cdot (9 - y) dy$$

since the radius of the disk, **r**, is the x-coordinate of the parabola.

The students with strongly developed **visual intelligence** will be able to picture the procedure in their mind, even if their mathematical intelligence is not as highly developed as their visual intelligence. Students with strong **mathematical intelligence** will be able to follow the string of connected ideas, even if their visual intelligence is not as highly developed as their mathematical intelligence.

For the student with strong **bodily intelligence** a “hands-on” approach is preferable. To optimize the learning process for this student, creating a paraboloid out of disks can create a connection or memory for this student which wasn’t possible in the visual/mathematical explanation. In this case the students are given this assignment:

- Draw a cross-section of the paraboloid,
- draw the cross-section of 18 one-half inch disks with radius, **r**, on the paraboloid cross-section,
- measure the radius of each disk,
- cut the disks out of one-half inch foam, and
- glue the disks together to form the paraboloid.

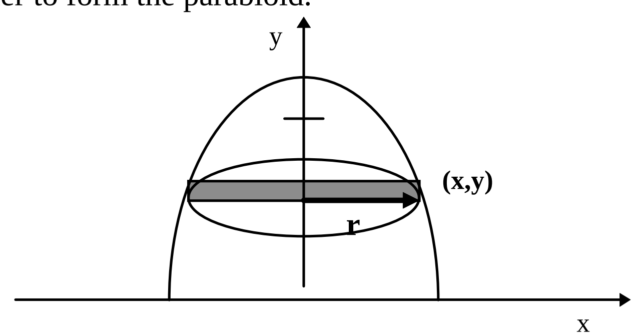

Figure 1

The “hands-on” approach can be done by an individual student or in small groups. When the exercise is done in small groups, the students with strong **interpersonal intelligence** learn by interacting with the group members. This also has a positive effect on the other students in the group since the students start teaching each other. If the group is made up of students with a variety of intelligences, then the concepts are reinforced in several ways. If the exercise is done by individual students, the students with strong **intrapersonal intelligence** can be prompted to *reflect* on how the equations relate to the physical model.

An assignment which requires the students to write a description of the process which they used to find the volume of a solid will help the student with strong **verbal intelligence** internalize this concept. Also, verbalizing what my thought process is when I solve this type of problem helps the students with strong **verbal and/or intrapersonal intelligence.** This discussion would start with something like "When I solve this type of problem, the first thing I ask myself is...".

Since each student in a class has varied levels of each of the intelligences, with some intelligences stronger than others, the use of all of these descriptions and assignments over the course of one or two lecture periods has created a better understanding and long-term comprehension of the material for many students.

2. Vector Addition

The addition of vectors is traditionally taught using an algebraic and trigonometric interpretation which relies on **mathematical intelligence** and a graphical interpretation which relies on **visual intelligence**. Teaching the concept of vector addition using a combination of **bodily intelligence** and **visual intelligence** is presented here. But first, a thumbnail sketch of the traditional method is outlined, so as to gives us a feeling for which intelligences are required to grasp the concept of vector addition when presented in this manner.

- A vector is defined as a quantity which has direction and magnitude.
- To represent the vector, an arrow is drawn whose length is proportional to the magnitude of the vector, at an angle, relative to the x-axis, which represents its direction. The tail of the arrow is at the beginning of the line and the head of the vector is at the end of the line.
- If the vector is placed at the origin of the x-y coordinate system, at the angle, θ, the vector can be broken down into two vectors which are parallel respectively to the x- and y-axes (i.e.: the x and y components of the vector). By dropping a line perpendicular to the x-axis from the head of the arrow aright triangle is formed. Using the Pythagorean theorem, with the sides of the triangle representing the x-and y-components of the vector, the algebraic equations, $A_x = A \cdot \cos\theta$, $A_y = A \cdot \sin\theta$ and $A = \sqrt{A_x^2 + A_y^2}$ are self evident.
- And of course, it follows that if you are adding two vectors, A and B, you can add the x-components of the two vectors to find the x-component of the resulting vector , $R_x = A_x + B_x$, and likewise, the y-component of the resulting vector, $R_y = A_y + B_y$. Again, using the Pythagorean theorem, the resultant vector is $R = \sqrt{R_x^2 + R_y^2}$.

The students with strong **mathematical intelligence** will be able to follow this long sequence of reasoning and arrive at the appropriate conclusions and an understanding of vector addition. Student with strong **visual intelligence** will understand the concept if each step of the sequence is shown graphically. The student with both strong mathematical and strong visual intelligences will gain the most from this traditional presentation of vector addition. It is our experience that this leaves a large majority of students struggling with the concept.

A model which physically shows the concepts of components of vectors and vector addition can be made using projection lamps placed perpendicular to the x- and y-axes, which shine down and across from the right respectively, onto wooden arrows such that shadows are formed on two projection screens which are in the y-z and x-z planes. The shadows are the lengths of the x-and y-components of the vectors.

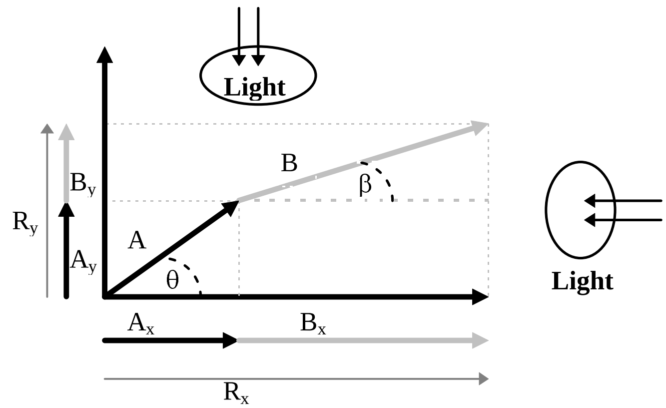

Figure 2

Students with a strong **bodily intelligence** are able to grasp these concepts more easily since the arrows are physical objects which can be picked up, the angles can be changed by physically moving the arrows, and the shadows are a result of the lights shining on the arrows, another physical phenomena. This experiment is also extremely visual.

We have found that a variation on this physical experiment in which the students imagine lights shining on imaginary arrows which are represented by a chalk drawing has been very successful. To introduce the concept of components of vectors, we ask the students to "think physical". A picture of the projection setup, as in Figure 2, is drawn on the board and the students are asked to imagine this setup:

- Imagine an x-y, cartesian coordinate system in which a wooden arrow represents vector A.
- Projection lamps are aimed from above down towards a planar screen containing the x-axis and from the right towards a planar screen containing the y-axis. The screens intersect at the origin of the coordinates along a line perpendicular to the x-y plane.
- Next consider the shadows which are cast on the two screens
- Let A be the length of the wooden arrow, vector A,
- Let A_x be the length of the shadow on the x-axis screen,
- Let A_y be the length of the shadow on the y-axis screen,
- Notice that the length of the shadows is the same as the sides of the right triangle which is formed by the wooden arrow , the x-axis, and a line drawn from the head of the arrow perpendicular to the x-axis.

Now, using the definitions of the trigonometric functions sine and cosine, the algebraic representation of the vector components begins to make more sense to many students.

Now that the students have the concept of components of a single vector, a second vector is introduced and the students are asked to add vector A to vector B.

- Place arrow A at the origin at an angle θ.
- Place arrow B so that its tail is at the head of arrow A and it is at an angle β with the horizon.
- Imagine the shadow that the projection lamps are making on the two screens.

At this point the resultant vector, R, can be drawn on the chalk drawing.

- Imagine the shadow that this resultant arrow would cast.
- Compare the lengths of the shadows on the screens.

Students can be asked to come to the board and using different colored chalk draw the shadows cast by each of the arrows; $R_{x,}$, A_x, and B_x on the screen containing the x-axis and $R_{y,}$, A_y, and B_y on the screen containing the y-axis.

- Compare the lengths of the shadows.

It is precisely at this point when students can see that the equation for the x-component of the resultant vector is the sum of the x-components of the two vectors, $R_x = A_x + B_x$; and similarly $R_y = A_y + B_y$.

The significance of this presentation is that: (1) students were not presented with an actual physical model, but rather were asked to imagine one, with the help of a chalk drawing and (2) by visualizing the shadows cast by the imaginary wooden arrows bathed in imaginary light on imaginary screens, and by observing the relationships among the lengths of the imaginary shadows (vector components), the algebraic equations emerged as self-evident and obvious to the students.

This exercise also gave us the opportunity to present a skill to the class, that of imagining a phenomena, which is very important in the fields of engineering and science. This skill is generally very strong in young children and tends to diminish significantly by the time students are in college, unless they are prompted to utilize this skill..

Our experience is that the degree of student satisfaction and intuitive “ownership” of the equations, when derived solely from algebraic and trigonometric relations without the shadows to “observe” is not as great. The shadow approach seems to facilitate synergy between the students’ **visual, mathematical, and bodily** intelligences that leads to a more successful comprehension outcome.

Results

At this point, the results which we have gathered are all anecdotal from students and our personal recognition of when particular students have mastered the concepts involved. Since we teach a sequence of courses and get to know some of the students over several semesters, we have been able to identify a particular students strong intelligences and have experiment with different approaches with that particular student. In this one-on-one situation direct correlations between the students strongest intelligence and the presentation method which the student found most successful was apparent.

Correlations can also be made between a student's intelligence area and their comprehension based on exam scores. Analysis of student grades on particular exam questions has shown that when an exam questions is posed using a single intelligence, such as verbal or visual, the students which are stronger in that intelligence receive better scores.

The concept areas which we have developed "MI lectures" for are those areas which we have found that students have the most difficulty with and those areas which we have identified as having the most long-term impact on the students continued learning.

Conclusions

Exclusive focus on linguistic and mathematical intelligences may short change individuals with strong skills in other intelligences. Therefore, it is necessary to present material using many of the intelligences so that a broader spectrum of students can attain their maximum potential. Since assessment of knowledge is typically done using linguistic and mathematical skills, this is another area which deserves further research and development. Significant work has been done by Thomas Armstrong in his book *Multiple Intelligences in the Classroom.* While his work is geared towards elementary and secondary education, his development of MI and Classroom Management is readily applicable in the college environment.[1]

It is our experience that applying MI theory has been time consuming, but the results have been extremely effective. Gardner points out that not all material can be taught with all of the intelligences[4]. We have focused our energies on developing presentations which use as many of the intelligences as possible. However, you will notice that musical intelligence was not used in either of the applications in this paper. It doesn't make sense to try to use an intelligence just for the sake of using every intelligence. Of course, the presenter's strengths also impact how comfortable it is to use a particular intelligence.

Formal assessment of student outcome reached by teaching to many intelligences will require a controlled study. This is planned in our future research.

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