Chapter II

THEORETICAL OVERVIEW

- Theoretical Overview of Mathematics Anxiety
- Theoretical Overview of Cognitively Guided Instruction
- Theoretical Overview of Instructional Strategy
THEORETICAL OVERVIEW

A thorough analysis of the theoretical background of the various concepts and variables related to the study helps to get a meaningful and deeper insight for designing the study.

This chapter has been devoted for presenting theoretical overview of Mathematics Anxiety, Cognitively Guided Instruction and Instructional strategy and these are presented under the following headings.

- Theoretical Overview of Mathematics Anxiety
- Theoretical Overview of Cognitively Guided Instruction
- Theoretical Overview of Instructional Strategy

Theoretical Overview of Mathematics Anxiety

Mathematics Anxiety- Conceptual framework

Mathematics anxiety is an intense emotional feeling of anxiety that people have about their ability to understand and do mathematics. People who suffer from mathematics anxiety feel that they are incapable of doing activities and classes that involve mathematics. Some math anxious people even have a fear of mathematics; it’s called ‘math phobia’. “Mathematics anxiety is an emotional rather than intellectual problem. As it interferes with a person’s mathematics learning ability, it becomes an intellectual problem”.

Researchers’ interest in mathematics anxiety started in the early 1950s with the observations of mathematics teachers. In 1957, Dreger and Aiken introduced mathematics anxiety as a new term to describe students’ attitudinal difficulties with Mathematics (Baloglu and Zelhart, 2007).

Different researchers had defined mathematics anxiety in a variety of ways. Some of the definitions are as follows:
According to Dreger and Aiken (1957) mathematics anxiety “is the presence of a syndrome of emotional reactions to arithmetic and mathematics”.

Richardson and Suinn (1972) defined mathematics anxiety as “feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems”.

Tobias and Weissbrod (1980) describe math anxiety as “the panic, helplessness, paralysis, and mental disorganization that arises among some people when they are required to solve a mathematical problem”.

Suinn, Taylor and Edwards (1988) defined mathematics anxiety as “feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations”.

According to Ashcraft (2002) mathematics anxiety is “a feeling of tension, apprehension, or fear that interferes with Math performance”.

Brady and Bowd (2005) defined mathematics anxiety as a combination of “debilitating test stress, low self confidence, fear of failure, and negative attitudes toward mathematics learning”.

Mathematics anxiety has psychological as well as physical symptoms. Some of the psychological symptoms of mathematics anxiety are panic or fear, worry and apprehension, desire to flee the situation or avoid it altogether, a feeling of helplessness or inability to cope, mental disorganization, incoherent thinking, inability to recall material studied etc. Some of the physical symptoms of mathematics anxiety are queasy stomach, clammy hands and feet, increased or irregular heartbeat, muscle tension, feeling faint, shortness of breath etc.
Where Does Mathematics Anxiety Come From?

There are many reasons for development of mathematics anxiety in a student.

Mathematics Anxiety can be related to:

1) Attitudes of parents, teachers or other people in the learning environment.

2) Impact of some specific incident in a Student’s mathematics history, which was frightening or embarrassing.

3) Teaching techniques which emphasize-time limits, the right answer, speed in getting the answer, competition among students, working in isolation, memorization rather than understanding.

4) Student attitudes like distrust of intuition or ability, negative self-talk, giving up before beginning, depression and feelings of failure, expectations of divine intervention.

5) Nature of mathematics itself, which requires students to think clearly, cleanly and often abstractly.

6) Mishandling of any of the mathematics disabilities like
   a) Difficulty with basic mathematics facts and memory.
   b) Weakness in doing calculations.
   c) Inability to apply mathematics concepts.
   d) Struggles with visual and spatial relationship.

7) A mathematics disability like dyscalculia or weak learning styles.

Although there are many reasons for mathematics anxiety, usually mathematics anxiety stems from unpleasant experiences in mathematics. According to Greenwood (1984), “evidence suggests that mathematics anxiety results more from the way the subject is presented than from the subject itself”. Unfortunately, mathematics anxiety is often due to poor teaching and poor experiences in Mathematics.
Three practices that are a regular part of the mathematics classroom and cause great anxiety in many students are imposed authority, public exposure and time deadlines.

Theories related to mathematics anxiety

Traditional Arousal theory

The traditional arousal theorists state that there exists an optimal level of arousal around the middle of the arousal dimension. This idea is graphically represented as an inverted U-curve depicting a curvilinear relationship between anxiety and performance. Thus this arousal theory indicates that some anxiety is beneficial to performance, but after a certain point it undermines performance (Ma, 1999).

![Inverted U curve](image)

Figure 1. Inverted U curve

Several researchers have noted the nonlinear relationship between anxiety and mathematics achievement. Munz and Smouse’s (1968) inverted U curvilinear hypothesis “implies that there is a degree of arousal which is optimal for performing a given task.” According to this model, moderately anxious individuals perform better than “nonaffecteds” or “high affecteds”. (Bessant, 1995)
Two factor theory of test anxiety

Liebert and Morris (1967) were the first to propose a two factor model of test anxiety that distinguished between an affective ‘emotionality’ and a cognitive ‘worry’ dimension of test anxiety.

Affective test anxiety: refers to the emotionality component of anxiety displayed through feelings of nervousness, tension, dread, fear and unpleasant physiological reactions to testing situations.

Cognitive anxiety: refers to the worry component of anxiety, which is often displayed through negative expectations, preoccupation with and deprecatory thoughts about an anxiety causing situation.

This two factor model that taps both affective and cognitive dimensions has also been found to be relevant to math anxiety. However, the pattern of associations between the dimensions of math anxiety and mathematics performance appears to differ from that for test anxiety and performance i.e., where as the cognitive worry factor of general test anxiety is reported to correlate negatively with test performance, for measures of math anxiety it is the affective factor that correlates negatively with math performance (Ho et al., 2000).

Wigfield and Meece (1988) claims that the negative affective reactions component of math anxiety may be debilitating, while the cognitive component may actually have some positive motivational consequences for the amount of efforts students put into mathematics and thus for mathematics performance. Depending on the individual and the task a moderate amount of anxiety may then actually facilitate performance. Beyond a certain point, however anxiety becomes debilitating in terms of performance; particularly in the case of higher mental activities and conceptual processes. Thus although mathematics anxiety
may in some cases have positive effects, it is perhaps more important for educationalists to focus on its possible negative consequences for performance (Newstead, 1998).

**Linear Relationship between Mathematics Anxiety and Performance**

Most researchers however start with the linear notion that anxiety seriously impairs performance. Specifically, a higher level of anxiety is associated with a lower level of achievement. This negative relationship has been displayed across several age populations. Mathematics anxiety is negatively correlated with Mathematics performance among adults in general and college students in particular. This negative relationship also appears at the elementary and secondary school levels. Hembree (1990) reported an average negative correlation for school students and concluded that mathematics anxiety seriously constraints performance in mathematical tasks and that reduction in anxiety is consistently associated with improvement in achievement (Ma, 1999).

Studies show that the theoretical explanation of the negative relationship has roots in the theory of test anxiety. Many researchers view mathematics anxiety as a subject specific manifestation of test anxiety. Theoretical models of test anxiety are presumed to support math anxiety as well (Ho et al., 2000).

Two theoretical models of test anxiety have been influential in the research on mathematics anxiety.

**Interference model**

Based on the work of Liebert and Morris (1967); Mandler & Sarason (1952) and Wine (1971) researchers have described mathematics anxiety as a disturbance of the recall of prior mathematics knowledge and experience. Consequently, a high level of anxiety causes a low level of achievement (Ma, 1999).
Deficit model

Tobias (1985) regarded mathematics anxiety as the remembrance of poor mathematics performance in the past and believed that poor performance causes high anxiety. According to this model, a student’s low level of math achievement is attributed to poor study habits and test taking skills instead of to mathematics anxiety (Ma, 1999). Within this model math anxiety does not cause poor performance, the reverse is true; an awareness of poor past performance causes mathematics anxiety.

Consequences of Mathematics Anxiety

Some of the consequences that result from being mathematics anxious as opposed to mathematic-confident include

A) The fear to perform tasks that are mathematically related to real life incidents.
B) Avoidance of mathematics classes
C) Belief that it is alright to fail or dislike mathematics
D) Feelings of physical illness, faintness, fear or panic.
E) An inability to perform in a test or test-like situations,
F) The utilization of tutoring sessions that provide little success

(Vinson, Haynes, Sloan and Gresham, 1997)

Many researchers have reported the consequences of being math anxious including the inability to do mathematics, the decline in mathematics achievement, the avoidance of mathematics courses, the limitation in selecting college courses and future careers, and the negative feelings of guilt and shame (Ma, 1999). The consequences also include avoidance of mathematics (Hembree, 1990), distress (Tobias, 1978; Buxton, 1981) and interference with conceptual thinking and memory processes (Skemp, 1986).
According to Tobias (1985), millions of adults are blocked from professional and personal opportunities because they fear or perform poorly in mathematics. For many, these negative experiences remain throughout their adult lives. “Mathematics anxiety paralyses a child’s capacity to learn mathematics even though the intellectual capability is there”. Overcoming mathematics anxiety is necessary for being successful in mathematics and in life.

**Relationship between Mathematics Anxiety and Mathematics Achievement**

The relationship between mathematics anxiety and mathematics achievement can change dramatically for students with different social and academic background characteristics. The social and academic characteristics of students appear to be the key to unfolding this achievement-anxiety dynamic. When student characteristics are diverse and unique, so are the relationships. Mathematics anxiety can facilitate or debilitate or can be unassociated with mathematics performance (Ma, 1999).

While it is agreed that anxiety can have a motivational role and therefore a positive effect on performance (Wigfield & Meece, 1988), it is also agreed that the higher mental processes such as problem solving and divergent thinking which are required for mathematics will be negatively influenced by mathematics anxiety (Newstead, 1998).

**Teacher Influences in Mathematics Anxiety**

A negative attitude towards mathematics is a growing barrier for many children to mathematics (Ashcraft, 2002; Popham, 2008; Rameau and Louime, 2007). The child’s educational context at home and at school can affect this attitude (Scarpello, 2007). The children begin to construct the foundations for future mathematical concepts during the first few months of life (Geist, 2001). Before a child can add or even count, they must construct ideas about
mathematics that cannot be directly taught. Many of these ideas are constructed through interaction with the surrounding environment and the adults in the environment. Ideas that will support formal mathematics latter in life such as order and sequence, seriation, comparisons, classification, addition and other more advanced mathematical skills have their genesis before the age of 5. As children enter formal schooling, the constructive process sometimes takes a turn for the worse (Geist, 2010). Studies have shown that at this time in children’s learning of mathematics, text books take over the process of teaching and the focus shifts from construction of concepts using children’s own mathematical thinking to teacher imposed methods of getting the correct answer. Teachers begin to focus on repetition and speed or ‘timed tests’ as important tool for improving mathematical prowess and skill which can undermine the child’s natural thinking process and lead to a negative attitude toward mathematics. Children begin to associate mathematics with boring work that does not relate to their everyday life. Instead of helping children develop fluency at computation and become more efficient at problem solving, the policies have produced students who rely more on rote memorization and have increased the level of anxiety in young children.

Mathematics anxiety is a learned emotional response that usually comes from negative experiences in working with teachers, tutors, classmates, parents or siblings (Harding & Terrell, 2006). Goulding, Rowland and Barber (2002) suggest that there are linkages between a teacher’s lack of subject knowledge and ability to effectively plan teaching material. These findings suggest that teachers who do not have a sufficient background in mathematics may struggle with the development of comprehensive lesson plans for their students. Moreover, Jackson and Leffingwell (1999) found that teacher is a prime determinant of mathematics anxiety and it is usually evident early on in the
primary grades. Many teachers who have mathematics anxiety themselves inadvertently pass it on to their student. They have found that teachers’ behaviours like negative speech, insufficient feedback, ignoring students or disappointing them may cause mathematics anxiety in a period starting from kindergarten to college. It was found by Johnson, Smith and Carinci (2010) that a number of studies had theorized that elementary school children do not develop mathematics anxiety independently but learn math anxious behaviours from teachers. According to Furner and Berman (2003), teachers who have negative feelings toward mathematics do not feel confident in teaching the subject, use poor instructional techniques, or are insensitive to students’ needs, can foster a dislike for mathematics and feelings of mathematics anxiety in their students.

Mathematics is often taught as if all the students are not just similar, but identical in terms of ability, preferred learning styles, and pace of working (Boaler, 1997). Every child learns differently. They also respond differently to different instructional approaches (Leedy, LaLonde and Runk, 2003). Methods that emphasize the primacy of correct answers over concept development, competition and speed over understanding and rote repetition over critical thinking will exacerbate the problem. Research has shown that these methods inherently create anxiety among children.

So overcoming mathematics anxiety involves re-examining the methods of teaching mathematics in the classrooms. There are strategies that can reduce mathematics anxiety of students.

**Strategies for Reducing or Overcoming Mathematics Anxiety of Students**

Teachers have a major role in helping their children to reduce or overcome mathematics anxiety. They have to ensure students understand the mathematics being presented to them. According to Furner and Berman (2003),
teachers benefit children most when they encourage them to share their thinking process and justify their answers out loud or in writing as they perform mathematics operations. With less emphasis on right or wrong and more emphasis on process teachers can help to alleviate students’ anxiety about mathematics. National Council of Teachers of Mathematics (NCTM) suggestions for teachers seeking to prevent mathematics anxiety include:

- Accommodating for different learning styles
- Creating a variety of testing environments
- Designing positive experiences in mathematics classes
- Refraining from tying self esteem to success in math
- Emphasizing that everyone makes mistakes in mathematics
- Making math relevant
- Letting students have some input into their own evaluations
- Allowing for different social approaches to learn mathematics
- Emphasizing the importance of original, quality thinking rather than rote manipulation of formulae

Cruikshank and Sheffield, 1992 (as cited in Johnson, Smith and Carinci, 2010) suggested that in order to establish a positive classroom climate for teaching mathematics teachers should: show that they like mathematics; make mathematics enjoyable; show the use of mathematics in careers and everyday life; adapt instruction according to students’ interests; establish short term attainable goals; provide successful activities; and use meaningful methods so that mathematics makes sense.

So it is important that teachers make efforts towards selecting teaching methods that cater to the needs of individual child and creating a student friendly atmosphere in the classroom.
Some of the strategies that help in alleviating mathematics anxiety are

**Visual Learning**

Visual learning is a proven teaching method in which ideas, concepts, data and other information are associated with images and represented graphically. Visual learning when combined with technology, enable students clarify thoughts, organize and analyze information, think critically and integrate new knowledge by visually seeing how items can be grouped and organized. Working visually inspires students to tap into their own creativity, to clarify their thoughts, reinforce understanding, integrate new knowledge and identify misconceptions. With visual learning, students use manipulatives, diagram and plots to display large amounts of information in ways that are easy to understand and help reveal relationship and patterns.

**Techniques Used in Visual Learning**

Some of the techniques used in visual learning to enhance thinking and learning skills are;

**Webs:** Webs are visual maps that show how different categories of information relate to one another. They provide structure for ideas and give students a flexible framework for organizing and prioritizing information. Typically, major topics or central concepts are at the centre of the web. Links from the centre connect supporting details or ideas with core concept or topic. Webbing is an effective technique to use in small group settings. As students work cooperatively, they can build collaborative webs incorporating the thoughts and contributions of each group member.

**Idea Maps:** Idea map connects key words, symbols, colours and graphics to form non-linear networks of potential ideas and thoughts. Idea maps help in writing assignments, in projects or presentations. This visual learning
technique stimulates students to generate ideas, follow them through and develop their thoughts visually. Idea maps help students brainstorm, solve problems and plan their work.

**Concept Maps:** Two or more concepts are linked by words that describe their relationship, i.e., graphic illustrations of the relationships between information. Concept maps encourage understanding by helping students organize and enhance their knowledge on any topic. They help students learn new information by integrating each new idea into their existing body of knowledge. Concept maps are ideal for measuring the growth of student learning. As students create concept maps, they reiterate ideas using their own words. Misdirected links or wrong connections alert educators to what students do not understand, providing an accurate, objective way to evaluate areas in which students do not yet grasp concepts fully.

**Plots, Graphs and Charts:** Plots, Graphs and Charts are great ways for the student to visualize the data. As students explore the way data moves through various plot types, they discover meaning from the visual representation. Some of the various plots are Venn diagrams, Pie graph, and Vertical Bar Graph. Venn Diagrams are a powerful way to describe and compare attributes by separating objects into groups based on their characteristics. Venn plots show relationships between mathematical sets or can be used to identify the commonalities and differences between things, ideas or physical attributes. Pie graphs are used to graphically represent the distribution of the entire set of data. Patterns can be easily identified, as well as the values that have the largest or smallest representations. Pie graphs can be used to illustrate percentages of a whole or to numerically represent a category of facts. Vertical bar graphs are used to represent a range of data for one variable. These are ideal for comparison activities.
**Accepting different approaches to problem solving**

Students who suffer from mathematics anxiety are very uncomfortable with problem solving. Often this is because they are certain, there is one right way, and they just don’t have it. Mathematics is usually taught as a right and wrong subject and as if getting the right answer is paramount. Additionally, the subject is often taught as if there is only a right way to solve a problem and any other approaches would be wrong, even if students get right answer through another approach. When learning understanding the concepts should be paramount. But with a right or wrong approach to teaching mathematics, students are encouraged not to try, not to experiment, not to find algorithms that work for them, and not to take risks.

So mathematics anxiety can be reduced by helping the students solve problems. Teachers can show them different approaches. It can be very helpful to encourage students to talk his way through a problem, even if it’s very round about. Teachers should try not to rush, or guide. Let students feel that there is no one way to get to the answer. And that the most direct way isn’t the only way or even the best way. Understanding the best way comes from having taken the long way around for most of us. Teachers can replace anxiety with greater comfort, simply by replacing the attitude and experience of problem solving.

**Teaching taking into consideration different learning styles of students**

The theory of Multiple Intelligence addresses the different learning styles. Lessons are to be presented for visual/spatial, logical/mathematical, musical, body/kinesthetic, interpersonal and intrapersonal and verbal/linguistic learners. Everyone is capable of learning but may learn in different ways. Therefore, lessons must be presented in a variety of ways. For example, different ways to teach a new concept can be through play acting, co-operative
Theoretical Overview

groups, visual aids, hands on activities and technology. As a result once young children take mathematics as fun, they will enjoy it and mathematics could remain with them throughout the rest of their lives.

Relating mathematics concepts to everyday life

Students today need practical mathematics. Therefore mathematics needs to be relevant to their everyday lives. Students enjoy experimenting. To learn mathematics, students must be engaged in exploring, conjecturing and thinking rather than, engaged only in rote learning of rules and procedures. Studies have shown students learn best when they are active rather than passive learners (Spikell, 1993). Students should be given examples that are relevant outside the classroom. According to Brady and Bowd (2005) it is important for students to make connections to real world applications in order to foster understanding and engagement in mathematics. Helping students see how mathematics is used in their lives can reduce anxiety.

Creating a non threatening learning environment

Creating a comfortable, calm, non-threatening learning environment in the mathematics classroom helps. To develop a positive class room culture conducive to enabling all students to learn important mathematics: select an activity that students could relate to; use many strategies to include all learners and to promote equity; provide support to students whenever they need it (Roddick and spitzer, 2010). Teachers should demonstrate caring for students’ feelings and learning. Encourage students to ask questions and be willing to answer any and all that arise. Active learners ask critical questions and some teachers may find these questions annoying or difficult to answer and respond with hostility and contempt. Better teachers respond eagerly to these questions and use them to help the students to deepen their understanding by examining
alternative methods. Then students can choose for themselves which method they prefer. This process can result in meaningful class discussions. Handling incorrect responses positively is important for encouraging student involvement and to enhance confidence. Teachers should never make a student feel ‘stupid’ deliberately or unintentionally. They should not prejudge a student’s ability or make assumptions about a student’s motivation, without exploring the background of the student. Teachers have to make efforts to become comfortable with each individual student and to show compassion.

**Teaching for understanding**

Teachers should teach for understanding, not just replication of the procedure demonstrated. Encourage students to maximize their ability to learn and not to give up. Teachers should worry more about student understanding than the quota of material to be covered for the day. Every student should not be expected to learn the first time itself when something is taught. Students need time to internalize what is being taught. Understanding mathematics is critical. So teachers can emphasize the importance of original thinking rather than rote learning of formulae and procedures.

**Avoiding negative experiences in mathematics classroom**

Students’ prior negative experiences in mathematics class when learning mathematics are often transferred and cause a lack of understanding of mathematics. Mathematics must be looked up in a positive light to reduce anxiety. Avoid forcing anxious students into intimidating circumstances, such as working problems on the board or being singled out to answer a question in class. Provide students alternative ways of participating in class until their confidence level improves. It is important to note that unlike general anxiety mathematics anxiety can be traced back to some specific previous educational
experiences. So it is necessary to avoid negative experiences related to mathematics teaching and learning.

**Theoretical Overview of Cognitively Guided Instruction**

**Cognitively Guided Instruction**

Cognitively Guided Instruction (CGI) is an alternative way to teach and learn mathematics from an early age where students start with concrete demonstration of what story problems are demanding and eventually work towards abstract representation by inventing their own algorithms to solve story problems. It was developed by Thomas Carpenter, Elizabeth Fennema, Penelope Peterson, Megan Loef Franke and Linda Levi. Instead of memorizing number facts, students construct their knowledge in any way possible because all methods of findings solutions are accepted and critiqued until the desired final answers are correct. Essentially “Children are not shown how to solve problems, instead each child solves them in any way that he or she can, and then shows how the problem was solved with peers and teachers” (Secada, Fennema & Adajian, 1995).

Cognitively Guided Instruction is a style of teaching based on years of research showing that people learn beginning mathematical concepts linearly. i.e., there are clear stages that are passed through in a particular order. It leads to student centered learning and stimulates discussion about multiple approaches to solve the same problem (Ruppert, 2010). Cognitively Guided Instruction focuses on the learning process and teaching great problem solving skills, instead of trying to memorize facts.

**Definition of cognitively guided instruction**

Cognitively Guided Instruction is “a program based on an integrated program of research on
a) The development of students’ mathematical thinking.

b) Instruction that influences that development.

c) Teacher’s knowledge and believes that influence their instructional practices, and

d) The way that teacher’s knowledge, believes and practices are influenced by their understanding of students’ mathematical thinking”

(Carpenter, Fennemma, Franke, Levi, Empson, 1999)

**Features of cognitively guided instruction classroom**

It’s not easy to describe a typical Cognitively Guided Instruction classroom because each one is unique and can appear to be quite different from other Cognitively Guided Instruction classrooms. In some classes whole group instruction is used. In others children spend most of their time working in learning centers. In some classes, children create many of the problems to be solved. In spite of the apparent diversity, there are similarities that can be seen across most Cognitively Guided Instruction classrooms. The similarities or features are:

**Basing the curriculum on problem solving**

In Cognitively Guided Instruction classes, all learning activities require problems solving. Children learn concepts and computation skills as they solve a variety of mathematics problems often set in story contexts. Sometimes problems are set in other formats like writing number sentences that equal a certain number, finding several ways to add 2 or 3 digit numbers, or discussing a mathematical concept like odd or even numbers. The critical consideration is that each child is actively involved in deciding how best to resolve a mathematical situation.
Unlike the traditional instruction in which the content to be learned is clearly sequenced (addition before subtraction, etc.) and where children learn skills before they use them to solve problems, the curriculum in Cognitively Guided Instruction classes is integrated. For e.g.: children do not learn number facts as isolated bits of instruction. Rather they learn them as they repeatedly solve problems, so that they begin to see relationships between various facts. In summary, children in Cognitively Guided Instruction classes learn mathematics with understanding through problem solving. Both word problems and symbolic problems are vehicles through which children learn mathematical concepts and skills. Although teachers choose problems so that they will enhance children’s development, in most cases, teachers do not provide explicit instruction on problem solving strategies, which becomes more efficient and abstract over time. Skills and number facts are learned in the process of problem solving and are thus learned with understanding rather than learned as isolated pieces of information.

**Communicating about problem solving**

Closely integrated with problem solving is communicating about one’s thinking. This communication usually takes the form of talking, writing or drawing pictures about how problems have been solved, and it serves a variety of purposes. It encourages children to think about or reflect on what they had done. It encourages understanding, because in order to be able to report they have to understand what they had done. It also enables the teacher to assess a child’s thinking while at the same time allowing other children to hear a variety of strategies. In Cognitively Guided Instruction classes, children operate at many different levels because children have the latitude to use a strategy that makes sense to them at the time. There is no prevalent strategy that all children use at a particular point in time. The variety of strategies in use at any given
time gives children the opportunity to learn more advanced strategies by listening to and interacting with other students who are using them. Children sharing strategies enable other children because they are listening carefully. If they are ready for it- and they have to be cognitively ready for that strategy – it might work for them.

**Creating a climate for communication**

Initially reporting how a problem has been solved is not easy, but it becomes easier as children have many experiences on reporting their strategies. Children are continually asked to report their thinking, and their peers are expected to listen to and value each other’s thinking. Gradually, children come to recognize that their thinking is important, and they come to value the process of doing mathematics.

Closely related to the idea of valuing each child’s thinking is the growing realization that there is no one best or “right” way to solve any problem. Any strategy that works and can be explained is important and correct. When a teacher expects and values a diversity of solution strategies, children realize that multiple strategies are not only acceptable but desirable. Thus no one’s solution strategy is any better than anyone else’s, and each child’s thinking becomes important to everyone.

**Teaching for understanding**

Because understanding is synonymous with seeing relationships, emphasizing relationships help to develop understanding. No one can give knowledge to anyone else. Each individual must develop understanding by constructing relationships. This does not mean that a teacher can never tell children anything; sometimes the best way to construct a relationship is to have someone else point it out. However, even when children are told something, in
order to understand they must be able to comprehend the relationship. Learning number facts is made much easier by understanding that these facts are related in specific ways and that there are principles governing these relationships. The basic principle that children should be encouraged to observe as early as possible is that number facts are related and these relationships can be used to simplify the process of solving problems. Thus teachers ask those questions designed to focus students’ attention on these relationships.

Not only there are relationships between number facts, there are relationships between solution strategies such as direct modeling, counting and using grouping by ten to solve problems. When children experience many solution strategies, they come to see how strategies are related. Children mature in their use of strategies when they see the relationships between less mature and more mature strategies. And teachers play a vital role in helping children to see these relationships.

**The Role of the Teacher**

A Cognitively Guided Instruction teachers’ role is active. They have to upgrade their understanding of how each child thinks, select activities that will engage all the children in problem solving and enable their mathematical knowledge to grow, and create a learning environment where all children are able to communicate about their thinking and feel good about them in relation to mathematics.

*Understanding students’ mathematical thinking*

The framework of children’s thinking provides a basis for understanding critical components of almost all children’s thinking. Although it appears complex at first, its coherence becomes more and more visible as a Cognitively Guided Instruction classroom develops. Rather than having to remember unrelated details, each child’s thinking can be understood in relation to the
framework. The framework provides a basis for understanding why a child is able to solve certain problems and not able to solve others. The path of development of ideas becomes visible, so it is possible to predict how children’s thinking will grow.

**Planning for instruction**

In Cognitively Guided Instruction classes, decisions about what to teach and when to teach it are based on what children understand. Instruction is based on what children understand and can learn. Teachers plan instruction keeping this idea in mind.

**Using knowledge of children’s thinking**

Using knowledge of children’s thinking is not easy. Cognitively Guided Instruction teachers continuously grow in their abilities to use their children’s knowledge to select problems, to question children in a way that both eliciting their thinking and helps them in problem solving and to understand their children’s thinking. All this information helps the teachers to structure the mathematical learning events so that the children develop their mathematical knowledge. In a very general term, Cognitively Guided Instruction teachers understand the way children think, understand what makes problems easier or more difficult to solve, and then make decisions that enable children to engage in successful problem solving with problems that are neither too easy nor too difficult.

**Encouraging children’s mathematical development**

Cognitively Guided Instruction teachers provide problem solving experiences that enable each child’s knowledge to grow. Ideas that are important for children to learn are not ignored, nor taught incidentally. Problem Solving experiences are chosen in which the ideas to be learned can be explored.
Through sensitive questioning, children can be encouraged to focus on and discuss the selected ideas; thus their mathematical knowledge grows and develops.

Children choose strategies to solve problems for a variety of reasons, and they can be encouraged to move to more mature solution strategies. Consciously selecting problems to be solved, asking children to solve problems in more than one way, being sure that children hear solution strategies that are different from the ones they used, and discussing how various solution strategies are alike or different are just a few ways that children can be encouraged to develop their problem solving skills.

Although teacher’s primary responsibility is not to demonstrate a prescribed sequence of procedures, teachers do play a critical role in their students’ learning. A few of such strategies are listed below.

1. Listening to children to figure out what they understand
2. Selecting and adapting problems so that the problems connect to and extend the knowledge that the children have already acquired
3. Supporting children’s learning by introducing appropriate symbols and ways of organizing and representing children’s ideas
4. Providing a forum and active listening support for children to discuss alternative ways of thinking about problems and the concepts they embody

While not offering prescriptions about how and what to teach, CGI provide a great deal of support to help teachers to:

a) Understand their students’ thinking
b) Select and sequence appropriate problems
c) Introduce notation to represent students’ strategies, and
d) Engage students in productive discussion
Learning to listen to students

Listening is a teaching practice that can profoundly influence what students learn and how they see themselves as mathematical thinkers. The teacher’s listening teaches students to pay attention to and value their own ideas and the ideas of others.

This image of teaching is different from the one that many teachers of mathematics hold. All teachers ask questions and listen to students’ answers, but the listening is aimed at assessing whether students got what the teacher had explained rather than uncovering their understanding of the content. Listening with the intention to hear what a student has to say without imposing one’s own way of thinking is a significant challenge. It can be hard for a teacher to listen without correcting or providing hints to a child who is hesitating or struggling and to know what questions to ask next when a child uses an unfamiliar strategy.

Developing the ability to listen to children’s thinking and use it to guide instruction takes time. There are several interrelated skills that make up this ability, which cannot be learned all at once or in a short professional development session.

Some of the most important teaching skills include:

- Posing problems for children to solve using their own strategies
- Choosing or writing problems that elicit a variety of valid strategies and insights
- Adjusting problem difficulty so that children can use what they understand to solve problems
- Sequencing problems and number choices in developmentally appropriate ways
- Asking probing questions to clarify and extend children’s thinking
• Conducting discussions of students’ strategies so that students can make new mathematical connections
• Identifying the important mathematics in children’s thinking

A focus on posing problems and asking students how they solved them is a natural place to start. These two skills alone can help teachers to find out a great deal about what students understand and at the same time lead to more understanding for students.

Theoretical Overview of Instructional Strategy

Concept, Meaning and Definition

Teaching strategy seeks to establish the relationship between teaching and learning in view of achieving the objectives. It is a generalized plan for a lesson which includes structure, desired learner behaviour in terms of goals of instruction and an outline of planned tactics necessary to implement the strategy. A tactics of teaching is a unit of teacher behaviour which is helpful for achieving instructional objectives. Different types of tactics can be used in the same teaching strategy.

It is possible to develop appropriate teaching strategies for a given instructional objective, for a given group of learners and for known conditions under which the group has to learn. The specific and reproducible strategies can be developed by using available gadgets, equipments and materials.

Teaching strategy is a means to achieve the instructional objective. Different teaching strategies can be used to achieve different objectives of cognitive, affective and psychomotor domains. All teaching strategies are helpful in achieving cognitive objectives. But low order cognitive objectives (knowledge, comprehension and application) can be achieved by lecture, low
order affective objectives (receiving, responding and valuing) can be achieved by all teaching strategies. Low and high order of psychomotor objectives can be achieved by lesson demonstration, practical tutorials and independent study.

Selection of an appropriate teaching strategy is very much a matter of teacher’s effectiveness. There is a great importance for the interaction between student ability and teaching strategy. The teaching strategies are not equally effective for each learner. In selecting teaching strategies main emphasis is given to achieve some learning objective rather than student interest. The learning objectives and learning conditions are the main criteria for choosing appropriate teaching strategies.

**Definition of Instructional Strategy**

Stones and Morris (1977) defined instructional strategies as a “generalized plan for a lesson which includes structure, desired learner behaviour in terms of goals of instruction and an outline of planned tactics necessary to implement the strategy”.

**Functions of an Instructional Strategy**

Dick and Carey (1996) use the term instructional strategy to describe the process of sequencing and organizing content, specifying learning activities, and deciding how to deliver the content and activities.

An instructional strategy can perform several functions.

- It can be used as a prescription to develop instructional materials
- It can be used as a set of criteria to evaluate the existing materials.
- It can be used as a set of criteria and prescription to revise existing materials.
- It can be used as a frame work based on which to plan class lecture notes, interactive group exercises, and homework assignments.
Essentials of an Instructional Strategy

Creating an instructional strategy involves taking all the information accumulated to this point and generating an effective plan for presenting instruction to learners. Creating a strategy is not the same as actually developing instructional materials. The purpose of creating the strategy before developing the materials themselves is to outline how the instructional activities relate to the accomplishment of the objectives (Gagne, 1988). This will provide a clear plan for subsequent development. Dick and Carey (1996) describe four elements of an instructional strategy.

Element 1: Content Sequence and Clustering

Content Sequence

The first step in developing an instructional strategy is deciding on a teaching sequence and grouping of contents. Whether to develop a lesson, a course or an entire curriculum, decisions must be made regarding the sequencing of objectives. The best way to determine the sequence is to refer to instructional analysis. Generally begin with the lower level subordinate skills on the left and work way up through the hierarchy until the main goal step is reached. It’s not a good idea to present information about a skill until the information on all related subordinate skills have been presented. Work from bottom to top and left to right till all of the skills are covered.

Clustering Instruction

The next important consideration is how to group instructional activities. It is to be decided whether to present information to accomplish one objective at a time, or cluster several related objectives. Dick and Carey (1996) recommend taking the following factors into consideration when determining how much or how little instruction to present at any given time.
1. The age level of learners
2. The complexity of the material
3. The type of learning taking place.
4. Whether the activity can be varied, thereby focusing attention on the task.
5. The amount of time required to include all the events in the instructional strategy for each cluster of content presented.

**Element 2: Learning Components**

The next element in an instructional strategy is a description of the learning components for a set of instructional materials. Here Dick and Carey (1996) mention Gagne's nine events of instruction, which is a set of external teaching activities that support the internal processes of learning.

In order for instruction to bring about effective learning, it must be made to influence the internal processes of learning. Gagne believes that instruction is a deliberately arranged set of external events designed to support internal learning processes”. The kinds of processing presumed to occur during any single act of learning are summarized by Gagne as follows.

**Attention**

Determines the extent and nature of reception of incoming stimulation.

**Selective Perception (or pattern cognition)**

Transforms this stimulation into the form of object features, for storage in short term memory.

**Rehearsal**

Maintains and renews the items stored in short term memory.
**Semantic encoding**

Prepares information for long term storage.

**Retrieval, including search**

Returns stored information to the working memory or to a response generator.

**Response organization**

Selects and organizes performance.

**Feedback**

Provides the learner with information about performances and sets in motion the process of reinforcement.

**Executive control processes**

Select and activate cognitive strategies; these modify any or all of the previously listed internal processes.

Gagne’s events of instruction are designed to help learners get from where they are to where the teacher wants them to be.

The nine events of instruction are:

1. Gaining attention
2. Informing learner of objectives
4. Presenting the stimulus materials.
5. Providing learning guidance
6. Eliciting the performance
7. Providing feedback about performance correctness
8. Assessing the performance
9. Enhancing retention and transfer.
Each of these events may not be provided for every lesson. Sometimes one or more of the events may already be obvious to the learner and may not be needed.

**Element 3: Student Groupings**

The next element of an instructional strategy is how students will be grouped during instruction. The main things to consider are whether there are any requirements for social interaction explicit in the statement of the objective, in the performance environment, in the specific learning components being planned, or in personal views of the teacher.

**Element 4: Selection of Media and Delivery Systems**

Once decisions have been made about content sequencing and clustering, and the learning components have been planned, it is time to turn to select a delivery system for overall instructional system, along with media that will be used to present the information in the instruction.

Overall delivery system includes everything necessary to allow a particular instructional system to operate as it was intended and where it was intended. Some examples are:

- Classroom delivery
- Lecture
- Correspondence
- Video tape
- Video conference
- Computer based delivery
- Web based delivery
Once delivery system is chosen, various media can then be chosen to deliver the information and events of instruction. Media constitutes the physical elements in the learning environment. With which learners interact in order to learn something. The choice of media is done as part of the instructional strategy.

**Procedure for Development of an Instructional Strategy**

Dick and Carey (1996) suggest a sequence while creating instructional strategy.

This process has 5 steps:

1. **Sequence and cluster objectives**
2. **Plan pre-instructional assessment and follow through activities for the unit.**
3. **Plan the content presentation and student participation sections for each objectives or cluster of objectives.**
4. **Assign objectives to lesson and estimate time required for each.**
5. **Review the strategy to consolidate media selections and confirm or select a delivery system.**

The first two steps relate to the overall unit of instruction and not to the individual objectives within the lesson.

**Sequence and cluster objectives**

Consider both the sequence and the size of cluster that are appropriate for the attention span of students and the time available for each session. Indicate the clusters and then the objectives to be taught within each cluster. For designing a short lesson only one cluster is needed. However, a teacher may still have small groupings of objectives that he/she want to divide up with review and/or practice activities.
Plan pre-instructional, assessment, and follow through activities for the unit

During this step, the decisions about student grouping and media selection are to be taken. This step gives indication with regards to pre-instructional activities, assessment and follow through activities in narrative form using the following headings.

Pre-instructional activities

a) Motivation: ways of maintaining attention
b) Objectives
c) Student groupings and media selection (for pre-instructional activities)

Assessment

a) Pretest
b) Practice tests
c) Post test
d) Student groupings and media selection (for assessment activities)

Follow through activities

a) Memory aid - that will be developed to facilitate retention of information and skills
b) Transfer - special factors to be employed to facilitate performance transfer
c) Student groups and media selection (for follow through activities)

Next two steps relate to individual objectives or clusters of objectives within the unit of instruction.
Plan the content presentations and student participation sections for each objectives or cluster of objectives.

First list the objectives and then two sections.

**Content presentation**

- a) Content: Content for each objective
- b) Examples: also non examples
- c) Student grouping and media selection – for this activity

**Student Participation**

- a) Practice items – practice exercises
- b) Feed back – for practice exercises
- c) Student groupings and media selection

**Assign objectives to lessons and estimate time required for each**

Review sequence and clusters of objectives along with the pre-instructional activities, assessment, content presentation, student participation, and student groupings and media selections. Using all these information, along with the time frame for overall instructional unit, assign objectives to individual lessons. In a large unit of instruction the first lesson generally contains pre-instructional activities, while the last generally contains the assessment and/or follow through activities. There must be time for presentations, review and participation activities. This process can be performed for extended instructional units or for semester long planning.

**Review the strategy to consolidate media selections and confirm or select a delivery system**

In this final step review the instructional strategy to consolidate media selections and to make sure that they are compatible with delivery system. Look
Effectiveness of Cognitively Guided Instructional Strategy

over all selections to see if there are patterns on common media prescriptions across the objectives. Then see if these patterns fit with the chosen delivery system.

The planning of an instructional strategy is an important part of the instructional design process. The best lesson designs will demonstrate knowledge about the learners, the task reflected in the objectives and the effectiveness of teaching strategies.

Validation of an Instructional Strategy

The broad steps of validating the effectiveness of an instructional strategy are:

1. Develop the Instructional Strategy
2. Develop and select instructional materials
3. Design and conduct formative evaluation of instruction
4. Design and conduct summative evaluations of instructions.

Develop the instructional strategy

Going through five steps of development of an instructional strategy develop the instructional strategy. The strategy will be based on current theories of learning and results of learning research, the characteristics of the medium that will be used to deliver the instruction, content to be taught, and the characteristics of the learners who will receive the instruction. These features are used to develop or select materials or to develop a strategy for interactive classroom instruction.

Develop and select the instructional materials

In this step, the instructional strategy will be used to produce instruction. This typically includes a learner’s manual, instructional materials, and tests. (The terms instructional materials include all forms of instruction such as
instructor’s guides, student modules, overhead transparencies, videotapes, computer based multimedia formats, and web pages for distance learning). The decision to develop original materials will depend on the type of learning to be taught, availability of existing relevant materials, and developmental resources available.

**Design and conduct formative evaluation of instruction**

Following the completion of a draft of the instruction, a series of evaluation is conducted to collect data that are used to identify how to improve the instruction. The three types of formative evaluation are referred to as one-one evaluation, small group evaluation and field evaluation. Each type of evaluation provides the designer with a different type of information that can be used to improve the instruction. Data from the formative evaluation are summarized and interpreted to attempt to identify difficulties experienced by learners in achieving the objectives and relate these difficulties to specific deficiencies in the instruction. Data from a formative evaluation are not simply used to revise instruction itself, but are used to re examine the validity of the instructional analysis and the assumptions about the entry behaviours and characteristics of learners. It is necessary to re examine statements of performance objectives and test items in the light of collected data. The instructional strategy is reviewed and finally all this is incorporated into revisions of the instruction to make it a more effective instructional tool.

**Design and conduct summative evaluation**

Although summative evaluation is the culminating evaluation of the effectiveness of instruction, it is generally, not a part of the design process. It is an evaluation of the absolute and/or relative value or worth of the instruction and occurs only after the instruction has been formatively evaluated and sufficiently revised to meet the standards of the designer. Since the summative
evaluation usually does not involve the designer of the instruction but instead involves an independent evaluator, this component is not considered as an integral part of the instructional design process.

**Conclusion**

The theoretical overview helped the investigator to understand the construct Mathematical Anxiety in detail, to get acquainted with the nuances of Cognitively Guided Instruction and to get a clear idea about the development and validation of an instructional strategy. An analysis of the strategies for reducing mathematics anxiety and the features of the Cognitively Guided Instruction classroom reveal that it theoretically holds the potential to reduce the mathematics anxiety of students. In Cognitively Guided Instruction, for better instruction, maintaining a non threatening environment is necessary and teachers are required to teach for understanding and create a climate for communication. These are also essential requirements for reduction of mathematics anxiety of students.