**INFLUENCE OF SPATIAL ABILITY ON MATHEMATICAL**

**CREATIVITY OF HIGHER SECONDARY SCHOOL**

**STUDENTS IN KERALA**

**VIJITHA P**

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**MASTER OF EDUCATION**

****

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**UNIVERSITY OF CALICUT**

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**DECLARATION**

 I, VIJITHA.P do here by declare that this dissertation “**INFLUENCE OF SPATIAL ABILITY ON MATHEMATICAL CREATIVITY OF HIGHER SECONDARY SCHOOL STUDENTS IN KERALA**” has not been submitted by me for the award of any Degree, Diploma, Title or Recognition before.

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25.01.2016

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**CERTIFICATE**

I, Mr. Anees Mohammed. C, do hereby certify that this dissertation, “**INFLUENCE OF SPATIAL ABILITY ON MATHEMATICAL CREATIVITY OF HIGHER SECONDARY SCHOOL STUDENTS IN KERALA**” is a record of bonafide study and research carried out by **VIJITHA. P**, under my supervision and guidance.

Farook Training College, **Mr. ANEES MOHAMMED. C.**

25.01.2016 (Supervising Teacher)

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 **CHAPTER I**

**INTRODUCTION**

* ***Need and significance of the study***
* ***Statement of the problem***
* ***Definition of key terms***
* ***Variables of the study***
* ***Objectives of the study***
* ***Hypothesis of the study***
* ***Methodology***
* ***Statistical techniques***
* ***Scope and limitations of the study***
* ***Organization of the report***

Education is the process of enabling people not merely to live but to live adequately. It teaches the lesson of humanity. The overall progress of any country depends on its progress in education. Educated person contribute for the development of society. Thus education can be considered as the most important input for the development of an individual, society and nation. Education is a deliberate and conscious process in which the individual lives.

The cultural, scientific and social progress of any country depends on the extent of development of creativity among citizens. One of the goals of any education system should be fostering creative people. Out of all the talents creative talent is most important and is related with subject like mathematics. Mathematical Creativity and teaching and learning of mathematics are important aspect which need attention in the educational world in general and mathematics education in particular. Mathematics undoubtedly has universal application. It is the key and gate way of all sciences. Mathematics plays a role in the economical and social development of a country because it is the basis for all science and technology. Doing any profession cannot survive without knowledge of mathematics. The ultimate concept of space travel, newer and greater use of atomic energy, atomization, electronic devices and other developments are few examples of the greater demand for scientific and mathematical advent.

Mathematics is a vehicle to train a child to think, reason, and analyze logically. Nature of mathematics is appropriate to be used as a scaffold for fostering creativity. Creativity should be evident in the mathematical activities. There for one of the important tasks of mathematics education is to identify and develop mathematical creativity. Through mathematics learning students attain higher intellectual and mathematical abilities like logical reasoning, concentration, orderly presentation and precision and above all general problem solving abilities.

Mathematics education in school is more emphasized as it improves concept development, fosters higher cognitive abilities and skills. Mathematics is very useful subject for most vocations and higher specialized courses of learning. At the higher secondary and university stages, most of the physical and social sciences require the application of mathematics. No other subjects can be a substitute for mathematics. Mathematics curriculum has undergone various changes from time to time in accordance with the changing needs of the society.

 Mathematics also helps in the development of certain mental ability, ability to analyses a statement, to arrive at conclusions and reason out different situations. At school level, creativity in mathematics is generally related to problem solving. Students should be provided opportunities to engage in struggling to solve mathematics problems. Solving such mathematical problems could lead students to experience creativity in doing mathematics and also try to think as a mathematician, which means that students are encouraged to reflect on their own ideas.

Higher secondary classes are critical in the development of creative talents and have immense importance for building up our nation. Higher secondary classes are the last stage of schooling. After that each student turns to their own choices and chooses their streams according to their choice of profession.

Empirical studies are strongly recommended to discover creative environments which foster mathematical learning at all levels of schooling. Unfortunately teachers have not recognized the importance of creative thinking. Mathematical creativity has not been much emphasized in school curriculum or teaching strategies at school level.

Mathematical Creativity involves mathematical thinking, it is the mental activity involved in the abstraction and generalization of mathematical ideas. There are different types of thinking strategies needed for learning mathematics. Among these spatial thinking skills is very much important in developing mathematical creativity in the modern era. Spatial ability has been receiving a constructive amalgam of three mutually reinforcing components of space, tools of representation and process of reasoning.

Some researches recommend that mathematical performance of students can be improved by training them spatial tasks. The creativity of such students can be improved by practicing spatial ability. It predicts a young person’s achievement in science and technology, engineering, mathematics. They are crucial for career development as architect, sculptor, surgeon, but they get little attention in schools.

 Spatial ability is the ability to manipulate shapes into two dimensions or to visualize three dimensional objects presented as two dimensional pictures. Spatial ability is one of the factors of creativity in mathematics. Spatial ability is the capacity of an individual to deal with concrete material through visualization. It involves the ability to manipulate things mentally and to create a structure of plan in one’s mind. Also spatial training helps the students to understand the subject with ease and helps to develop proper caliber and creativity in mathematics. So the investigator selected the topic for the study.

**Need and Significance of the Study**

In the history of the world, there had been several philosophers, poets, writers and painters who were turned out of their school classes considered as backward students, but who created great works in their later life. Hence in modern times the progressive nations try to develop creativity in their new generations.

Some researchers reported that excellent content knowledge in mathematics help to develop mathematical creativity. On the other hand, student’s knowledge and familiarity with techniques and rules may limit their creative potential. Many researches are conducted scientifically to study the nature and identification of creativity and its relationship with the variables like aptitude, achievement, personality, and interest and socio economic status and there are some studies related to mathematical creativity. Therefore the concept of creativity occupies a very important place in educational psychology.

In general, most teachers think there are a single correct answer and one correct method to solve a mathematical problem. This is because traditional Mathematics education was intended to focus mostly on convergent thinking in which a student memorized existing mathematical rules and theorems and then applied them to problems to find one exclusive solution rather than to apply these rules and theorems in new and different ways.

Current emphasis on convergent thinking in the classroom reduces Mathematics to a set of skills to master and rules to memorize. Identification of mathematical talent using only on the basis of memorizing the works done in the classroom, neglects those who are creative and reflective. All students especially those with potential talent in mathematics, need academic rigor and challenges as well as creative opportunities to explore the nature of Mathematics and to employ the skills to have developed.

Spatial ability is important because it enhances the clear understanding in many areas of mathematics. Identifying students with exceptional spatial abilities has an important social function. Spatial ability is required in technical and design jobs where drawing and plans used, architecture, surveying, engineering, design. It is also important in some branches of science and technology where three dimensional components are interacting.

Imagination is more important than knowledge. One of the common denominations of peak performers is that they possess an above average ability to consciously practice task in their minds using visualization. We want such persons in our younger generations highly talented, creative for the progress of our nation.

The identification of Mathematical Creativity and Spatial Ability are important in the higher secondary level because these two factors influence their subsequent career development and contributions to our nation. So the investigator selected the topic for study.

**Statement of the Problem**

The study helps to find out the extent of mathematical creativity of higher secondary school students and the influence of spatial ability in developing mathematical creativity.

The proposed study entitled as “Influence of Spatial Ability on Mathematical Creativity of Higher Secondary School Students in Kerala”

**Variables Selected For the Study**

The present study in descriptive type and it includes two types of variables independent and dependent. The independent variable is spatial ability. Dependant variable is mathematical creativity with components fluency, flexibility, originality and sensibility to problems.

**Operational Definition of Key Words**

**Influence**

The dictionary meaning of influence is the effect of one person or thing on another. Influence is the ability to cause desirable and measurable actions and outcomes.

**Spatial Ability**

Spatial ability is the ability to interpret and make drawings, form mental images and visualize movement or change in those images.

**Mathematical Creativity**

Mathematical creativity as an ability to analyze a given a problem from different perspective like see patterns, difference and similarities, generate multiple ideas and choose a proper method to deal with unfamiliar mathematical situations.

**Higher Secondary School Students**

Higher secondary school students are the students’ studies in class XI and XII. In the present study students of class XII are taken as higher secondary school students**.**

**Objectives of the Study**

1. To find is there exists any significant relationship between spatial ability and mathematical creativity for the total sample.
2. To find is there exists any significant relationship between spatial ability and mathematical creativity for the sub samples based on
3. Gender
4. Board of education
5. Subject specifications
6. To find is there exists any significant difference in spatial ability based on sub samples
7. Gender
8. Board of education
9. Subject specifications
10. To find is there exists any significant difference in mathematical creativity based on sub samples
11. Gender
12. Board of education
13. Subject specifications

**Hypothesis of the Study**

1. There is no significant relationship between spatial ability and mathematical creativity for the total sample.
2. There is no significant relationship between spatial ability and mathematical creativity for the sub samples based on
	1. Gender
	2. Board of education
	3. Subject specifications
3. There is no significant difference in spatial ability based on sub samples
	1. Gender
	2. Board of education
	3. Subject specifications
4. There is no significant difference in mathematical creativity based on sub samples
	1. Gender
	2. Board of education
	3. Subject specifications

**Methodology of the Study**

**Method**

 Survey method was adopted for the present investigation.

**Sample**

A sample of 400 higher secondary school students was selected using stratified random sampling technique by giving due representation to gender, board of school, subject specifications.

**Tools Employed For the Collection of Data**

In the present study, the following tools were employed for collecting data

* For to measure Spatial Ability, the investigator prepared a ‘Spatial Ability Test’ with the help of supervising teacher.
* For to measure Mathematical Creativity, the investigator prepared ‘Mathematical Creativity Test’ with the help of supervising teacher.

**Statistical Techniques Used For Analyzing the Data**

The following are the tools used for the present study,

* Preliminary data analysis-Mean, Median, Mode, Standard Deviation, Skewness and Kurtosis.
* Pearson’s product moment correlation coefficient.
* Test of significance of mean difference for large independent sample (t-test).

**Scope and Limitation of the Study**

The present study is an attempt to examine the relationship between mathematical creativity and spatial ability of the higher secondary school students. For this study an appropriate tool were constructed by the investigator with the help of supervising teacher.

 Even though the aim of education is all round development of the children, only a privileged few are fortunate enough to get the right type of education so as to draw out the best in them. A large chunk of children are deprived not because of the education system, but we often ignore the individual difference in intelligence, creativity and mathematical ability of students. The investigator believes that proper understanding of the ability of the children will lead to a better result in education field.

 The findings of the study can help to redefine the process of instruction itself that will help to develop higher level of learning outcome including creativity. The new knowledge yielded by this study will help to subject teachers especially mathematics teachers school administrators, psychologists, curriculum planners and all those are concerned in the process of education.

**Limitation**

The present study is a humble attempt in the field of mathematics education. Due to the shortage of time the researcher failed to collect the data from large sample. The sample of the study was limited to 400 higher secondary school students in Malappuram, Kozhikode districts only. More generalized results could have obtained from the study of the sample if it were taken from all the districts of Kerala. The study covers only two variables. All the components mentioned by different experts are not considered while preparing the tool. The present study was conducted using tests only. More advanced standardized tests could be applied to deepen the reliability of the results of the study.

**Organization of the Report**

The report consist of five chapters

**Chapter I**

 This chapter presents a brief introduction of the problem need and significance, statement of the problem, definition of key terms, objectives of the study, design of the study and scope and limitations.

**Chapter II**

This chapter presents the review of related literature which includes the theoretical overview and review of related studies.

**Chapter III**

 Methodology of the study is described in third chapter under heading like design of the study, objectives, tools used for the data collection, preparation of tools, sample selected for the study, data collection procedure, consolidation of data and statistical techniques used for analyzing the data.

**Chapter IV**

Details of analysis, interpretation of the results and the discussion are included in chapter IV. It consist of ‘t’ test and Pearson’s product moment correlation coefficient.

**Chapter V**

 The concluding chapter gives description regarding the major findings educational implications, suggestions for further research.

 **CHAPTER II**

**REVIEW OF RELATED LITERATURE**

* ***Theoretical overview***
* ***Studies related to Spatial Ability and Mathematical Creativity***

**REVIEW OF RELATED LITERATURE**

Review of related literature is an important aspect of any investigation. It helps the researcher to acquaint himself with current knowledge in the field or area in which he is going to conduct research. Through the review of related literature the researcher can take decisions about methodology, the tools for the study.

 Review avoids duplication of work that has already been done and it helps the investigator to go deep in to the problem at hand and it helps to study the different aspects of the problem. It provides an insight into the methods, measures employed by others which will lead to a significant improvement of the research design.

 The present study is to find out if there exists any significant relation between Spatial Ability and Mathematical creativity of Higher Secondary School Students and if there exists any significant difference in the Spatial Ability and Mathematical Creativity between relevant subsamples.

 In this chapter the investigator presents the theoretical outline of variables mathematical creativity and spatial ability together with the review of previous studies related to variables.

 These are presented under the sections

1. Theoretical overview.
2. Review of related literature.

**Theoretical Overview**

**Creativity**

A review of related literature in the area of creativity makes it clear that substantiate research works in creativity begin at 1950’s only when J.P.Guilford and his associates gave a new direction to the study of the construct by giving it a new operational definition and new research instruments for measuring it. Creativity became an object of scientific study primarily because of the general interest in the study of individual differences.

 Even though there are number of definitions to creativity, there is no single universally accepted one.

 A large number of theories have been proposed to define Creativity as a psychological process. It includes J. P. Guilford’s (1959) psychometric theory, Wertheimer’s (1959) Gestalt theory, Torrance’s (1962) theory of creativity, Mednick’s ( 1962 ) associational theories, Sternberg and Lubart’s (1995) investment theories. All of these theories contribute to our understanding of creativity.

 The field of Creativity as it exists today emerged largely as a result of the pioneering efforts of J. P. Guilford and E. P. Torrance. Guilford and Torrance had many more agreements than disagreements about the nature of creativity and the ways to measure it.

J.P.Guilford (1959) remarked Creativity involves fluency, flexibility and originality. According to him Creativity is the

* Ability to go beyond the immediate solution.
* Ability to redefine the problem or some part of it.
* Ability to cope with ideas that are unusual and
* Ability to change or having new approach to the problem.

The present study is in tune with the above definition. The investigator prepared the tool for mathematical creativity on the theory of J.P.Guilford.

**Theory of Guilford**

The first scientific explanation of creativity is given by J. P. Guilford (1959, 1967) explained the construct creativity in general, in relation to the model of structure of intellect (SOI model). According to him any mental process or intellectual activity of the human being can be described in terms of three basic dimensions or parameters. S.K. Mangal (2007) clearly explained these three basic parameters and its specific factors as follows.

1. Operation

Operation is the act of thinking or way of processing the information.

1. Content

An operation is performed upon certain kinds of information. This information is called content.

1. Products

The ideas we come up with, i.e. the fruits of thinking.

Each of these parameters operation, content, products may be further subdivided into some specific factors or elements.

As a result, operations may be subdivided into five specific factors, contents into five and products into six. The interaction of these three parameters thus results in to 5x5x6 = 150 different elements or factors in one’s intelligence. These 150 factors or independent abilities of the human beings along with the basic parameters and their divisions can be represented through a model named as Guilford’s model of structure of intellect. The figure is shown below.

Auditory

Visual

Contents

Behavioral

Semantic

Symbolic

Units

Products

Relations

Classes

Systems

Implications

Transformations

Convergent production

Evaluation

Operations

Memory

Divergent production

Cognition

*Figure 1*.Guilford’s Model of the Structure of Intellect

 This model proposes that intelligence consist of 150 independent abilities that result from interaction of five type of contents, five types of operations and six types of products.

 A brief description about these parameters are given below

Contents (The type of information involved)

* Figural (Visual) – The properties of stimuli we can experience through visual sense. Color, size, shape, texture and other visual characters of figure.
* Figural (Auditory) – The properties of stimuli we can experience through auditory senses, e.g. voice and sound.
* Symbolic – Numbers, letters, symbols, designs.
* Semantic – The meaning of words, ideas.
* Behavioral – The actions and expressions of people.

Operation (The way of processing information)

* Cognition – Recognizing and recovering.
* Memory – Retaining and recalling the contents of thought.
* Divergent production – Producing a variety of ideas or solutions to a problem.
* Convergent production – Producing a single best solution to a problem.
* Evaluation – Taking decision about the nature of the intellectual contents or gathered information whether it is positive or negative, good or bad etc.

Products (The results obtained through operations)

* Units – Individual pieces of information limited in size, e.g. a single number, letter or word.
* Classes – Groups of units information related to each other on the basis of some common characteristics involving a higher order concept.
* Relations – A connection between concepts.
* Systems – An ordering or classification of relations.
* Transformation – Altering or reconstructing intellectual contents.
* Implications – Making inferences from separate pieces of information.

**Nature of Creative Thinking**

In an elaborated study by J.P.Guilford regarding the nature of human intelligence in 1967, a battery of tests was constructed and carefully analyzed. Out of this work came the concept of convergent and divergent thinking.

J.P. Guilford’s (1967) concepts of convergent and divergent thinking provide an excellent frame work for understanding creativity. Convergent thinking is logical, factual and conventional and focused on a problem until a solution is found. Convergent thinking involves the production of correct solution. It is a crucial factor in intelligence testing.

 Divergent thinking is loosely organized, only partially directed and unconventional. Unlike convergent thinking, divergent thinking produces answers that must be evaluated subjectively. Divergent thinking involves the production of multiple solutions or hypotheses. It is central in the creative process. Many possible solutions are explored in a short amount of time, and unexpected connections are drawn.

J.P.Guilford (1959, 1967) originally hypothesized that the three component factor of divergent thinking ability namely fluency, flexibility and originality account for the whole of creative thinking ability. Later Guilford presented his list of intellectual factors of creativity based on his own and other investigations. The factors of creativity presented are

1. Fluency (word fluency, ideational fluency, associational fluency and expressional fluency).
2. Flexibility (spontaneous flexibility, adaptive flexibility)
3. Originality
4. Elaboration
5. Redefinition
6. Sensitivity to problems

1. Fluency factors

 The term fluency according to Guilford is the number of appropriate responses one can produce in limited time when told to produce a list of items of a certain kind. The four fluency factors are

1. Word fluency: This refers to the ability to produce words containing a specific letter or combination of letters.
2. Ideational fluency: This refers to the ability to produce ideas to fulfill certain requirements. It gives something to write about.
3. Expressional fluency: This means the ability to put ideas into words.
4. Associational fluency: This pertains to the completion of relationships in distinction from ideational fluency which involves giving ideas that fit a class. It helps to find words with the right shading of meanings without the help of word finding aids.

2. Flexibility factors

Flexibility factors has been defined as a change of some kind – a change in the meaning, interpretation or use of something, a change in understanding of some tasks, a change in strategy in doing the task or, a change in the direction of thinking which may mean a new interpretation of the goal. The two flexibility factors are

1. Spontaneous flexibility: It is defined as the ability or disposition to produce a great variety of ideas with freedom. What is measured is the variation in the kind of responses.
2. Adaptive flexibility: this means a change of some kind- a change in the interpretation of the task, approach or strategy to a solution. This is seen best in type of problem that requires the most unusual type of solution.
3. Originality factors.

Originality means the ability to produce unusual or uncommon responses, remote associations or connections or clever responses. It is indicated by scores of some tests in which the keyed responses are weighted in proportion to their infrequency of occurrence in the population of examinees.

4. Elaboration

It deals with semantic elaboration asking respondents to fill in details as many as necessary to make a briefly attained activity work or to add to given lines to produce a meaningful figure. The score is based on the number of details drawn.

5. Redefinition

 It means defining or perceiving in a way different from the usual established or intended way, use and so on. Redefinition can be figural, symbolic or semantic.

6. Sensitivity to problems

 It involves seeing defects, needs, deficiencies, seeing the odd, the unusual and seeing what must be done.

 S.A. Chermahini (2011) explained the hypothetical chart of convergent thinking and divergent thinking in the research work about neural and cognitive mechanisms of creativity.

The hypothetical chart of divergent thinking is presented in Figure 2. The factors of creativity: fluency, flexibility, originality and elaboration are represented by number of circles, circles with same color, black circle with longest arrow and size of the circles respectively.

Hypothetical chart of convergent thinking is shown in figure 3. The correct solution is represented by black circle.

Idea 5

Idea 3

111

Idea 8

111

Idea 1

111

Idea 9

111

Idea 4

111

Idea 6

Idea 7

Idea 2

*Figure 2*.Hypothetical chart of divergent thinking

Data 4

111

Data 3

111

Data 2

Data 1

Data 5

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Data 8

111

Data 7

111

Data 6

111

*Figure 3*.Hypothetical chart of convergent thinking

**Mathematical Creativity**

 Several definitions for mathematical Creativity have been cited in the literature. The majority of the existing definitions of Mathematical Creativity are vague and there is not a specific conventional definition of Mathematical Creativity. Mathematical Creativity is often considered as the exclusive domain of professional mathematicians H.Poincare, Laycock, Ervynck, Bharath Sriraman.

Henry Poincare (1956)

 French mathematician Henry Poincare (1956) described fundamental aspect of Mathematical Creativity as ‘choice’ the ability to choose from the huge number of possible combinations of mathematical propositions, a minimal collection that leads to the proof. He believed that discovery in mathematics is combination of ideas and stated that there are a lot of these combination of ideas but a few of them are useful. In process of finding these useful combinations, a great number of combinations are constructed and then meaningful combinations are distinguished from meaningless ones. In other words creating could be defined as forming, recognizing and choosing important and useful combinations.

Laycock( 1970)

 Laycock (1970) described mathematical creativity as an ability to analyze a given problem from different perspective, see patterns, differences and similarities, generate multiple ides and choose a proper method to deal with unfamiliar mathematical situations.

Ervynck(1991)

According to Ervynck(1991) mathematical creativity is the ability to generate mathematical objects or the generation of a idea for coping of a mathematical problem with in a mathematical context. From this definition he derives the following characteristic features of mathematical creativity.

1. Relational

With the production of mathematical objects the individual has to discover conceptual links between two or several mathematical concepts, so that and interaction of ideas can be understood as single blocks, which can be combined differently.

1. Selective

With competition of different mathematical blocks the individual has to make a choice on one (at the best for the most useful idea). This character is similar to Poincare’s choice metaphor.

1. Compressed / briefly presentably

The individual has to find the suitable words or symbols for the presentation of mathematical ideas.

Ervynck (1991) asserts that creating useful mathematical concepts through combining previously known concepts or discovering unknown relations between mathematical facts can be considered as a creative act of doing mathematics. Also he emphasizes that creativity in mathematics plays a key role in the full cycle of advanced mathematical thinking which helps plausible conjectures to be made in order to develop mathematical theories and degenerate mathematical knowledge.

Ervynck described mathematical creativity in terms of three stages.

1. Stage 0 : Preliminary technical stage

This stage consists of some kind of technical or practical application of mathematical rules and procedures, without the user having any awareness of theoretical foundation.

1. Stage 1 : Algorithmic activity

Which consist of primarily of performing mathematical techniques such as explicitly applying an algorithm repeatedly.

1. Stage 2 : Creative activity

The third stage is referred to as creative (conceptual, constructive) activity. This is the stage in which true mathematical creativity occurs and consists of non algorithmic decision making.

 Although Ervynck tries to describe the process by which a mathematician arrives at the questions through his characterization of stage 0 to stage 1. His description of mathematical creativity is very similar to those of Poincare. In particular his use of the term ‘non algorithmic decision making’ is analogous to Poincare use of the ‘choice’.

B. Sriraman (2004,2005)

 According to Bharath Sriraman( 2004,2005) defining creativity just based on originality and usefulness is not practical for the identification and development of the creative thinking in students. Sriraman made distinction between definition of mathematical creativity at the professional level and at the school level.

 At the school level, one normally does not expect works of extra ordinary creativity; however, it is certainly feasible for students to offer new insights in to mathematical problem.

 At the professional level mathematical creativity can be defined as

1. The ability to produce original work that significantly extends the body of knowledge.
2. The ability to open up avenues of new question for other mathematicians.

At the school level:

1. The process that results in unusual (novel) and/or insightful solution to a given problem or analogous problems.
2. The formation of new question and/or possibilities that allow an old problem to be regarded from new angle.

**Spatial ability**

Spatial Ability research starts in the late 19th century, when Sir Francis Galton (1880) put forward his experimental inquiries into mental imagery. It gives a way to the evolution of Spatial Ability as a mental ability in the early 20thcentury.

 Spatial Ability as a cognitive construct has been studied by researchers on many dimensions and various perspectives. Majority of studies have focused on understanding and analyzing the factor structure, development, relation to general intelligence, sex differences and measurement of this comprehensive cognitive construct.

**Analysis of Definitions of Spatial Ability**

Thrustone (1938) referred Spatial Ability as the ‘space’ factor is generally defined as the ability to mentally manipulate shapes, sizes and distances in the absence of verbal or numerical symbols. The highlighted features of Spatial Ability are the following

* Mental manipulation of shapes, sizes and distances.
* Absence of verbal or numerical symbols.

According to Elliot and Smith (1983) spatial abilities entail visual problems or tasks that require individuals to estimate, predict or judge the relationships among figures or objects in different contexts. The highlighted features of Spatial Ability are the following

* Prediction of relationships among figures.

Linn and Petersen (1985) defined Spatial ability is the ability refers to skill in representing, transforming, generating and recalling symbolic, non linguistic information.

Lohman (1988) used the term Visual Ability instead of Spatial Ability. According to him Visual ability is the ability to generate, retain, retrieve and transform well structured visual image. So he considers capacity of generation, retention, retrieval and transformation of well structured visual images as the features of Spatial Ability.

Carroll (1993) referred Spatial Ability is the ability in forming internal mental representations of visual patterns and in using such representations in solving spatial problems. Carroll highlighted the following features of Spatial Ability.

* Ability of forming internal representation of visual patterns
* Making use of formed internal representation in solving spatial problems.

Sutton and Williams (2007) defined Spatial Ability as the performance on tasks that require the mental rotation of objects, ability to understand how objects appear in different positions and the ability to conceptualize how object relate to each other in space.

Sutton and Williams highlighted the following features of Spatial Ability.

* Spatial Ability is a performance
* Spatial Ability is the performance on tasks that require mental rotation of objects and the ability to understand how objects appear in different positions.
* Spatial Ability is the ability to conceptualize how objects relate to each other in space.

The above definition of spatial ability is to provide an overview of the changes undergone by the construct in course of time. The highlighted features of the definition pay way towards deduction of the constituent elements of Spatial Ability.

**Factors of spatial ability**

The factor structure of Spatial Ability has been an area of study since the mid 1940’s.

Guilford and Lacy (1947) introduced two factors or components of Spatial Ability they are

1. Spatial visualization

An ability to imagine the rotation of depicted objects, the folding and unfolding of flat patterns, the relative changes of position of objects in space, the motion of machinery.

1. Spatial orientation

 An ability to determine relationships between different spatially arranged stimuli and responses and the comprehension of the arrangement of elements within a visual stimulus pattern.

An extensive study by Mc Gee (1979) reviews the literature and shows that the reason for inconsistency and confusion concerning the structure of Spatial Ability is investigators inconsistent naming factors. Mc Gee (1979) concludes that there are two main factors Spatial Visualization and Spatial Orientation.

1. Spatial visualization

Ability to mentally Manipulate, rotate, twist and invert a pictorially represented stimulus object without reference to one’s self. This ability is measured by complex tests such as paper folding.

1. Spatial Orientation

Comprehension of arrangement of elements within a visual stimulus pattern and the aptitude to remain unconfused by the changing orientation in which a spatial configuration may be presented.

 According to Linn and Peterson there are three components for Spatial Ability. They are Mental Rotation, Spatial Perception and Spatial Visualization.

1. Mental Rotation

Ability to determine the new projection of a 2D or 3D object which has been rotated from a certain position.

1. Spatial Perception

 Ability to determine spatial relationships between two objects, most notably between an object and the test subject despite distracting information.

1. Spatial Visualization

The ability to manipulate information sequentially and spatially when several stages were needed to produce the correct solution.

According to Lohman (1988) there are three factors for spatial Ability.

1. Spatial Visualization

 In defining Spatial Visualization, Lohman agrees with Mc Gee.

1. Spatial Orientation

 In defining spatial Orientation, Lohman agrees with Mc Gee.

1. Speeded Rotation

Defined by tests in which subjects are required to determine whether given stimulus is a rotated version of a 2 dimensional target or is a rotated version of it. Speed of answering is a major factor in these tests.

 Carroll (1993) included 5 factors in his factor analysis of Spatial Ability

1. Spatial Visualization

Ability to manipulate visual pattern, as indicated by level of difficulty and complexity in visual stimulus material that can be handled successfully, without regard to the speed of task solution.

1. Spatial Relation

Another name for speeded rotation factor defined by Lohman (1988) for 3D objects. It is defined as the speed in manipulating relatively simple visual patterns by whatever means (rotation, transformation or otherwise)

1. Closure Speed

Speed in apprehending and identifying a visual pattern without knowing in advance what pattern is, when the pattern is obscured in some way.

1. Flexibility of closure

Speed in finding, apprehending and identifying a visual pattern, knowing in advance what is to be apprehended, when the pattern is disguised or obscured in some way.

1. Perceptual speed

Speed in finding a known visual pattern, or in accurately comparing one or more pattern, in a visual field such that the patterns are not disguised or obscured.

 Majority of the researchers advocated the existence of three spatial factors namely spatial visualization, spatial relation and spatial orientation. The definition of three factors given by the researchers clearly indicated a definite incoherence and non discrimination between the terms ‘orientation’ and ‘rotation’.

**Research Approaches in Spatial Ability**

* Psychometric research

The earliest approach in spatial domain. It focused on defining spatial ability as a discrete form of intelligence, separate from the general intelligence. It was characterized by the use of factor analysis to determine the underlying factors that account for spatial ability. Early research acknowledges the presence of single spatial factor. Subsequent research advocated the existence of multiple spatial factors. Psychometric studies paved way for the development of many spatial tests.

* Developmental research

Major goal of this research approach is to search solutions for queries related to the developmental perspectives of spatial ability. Its major focus is to trace the development of spatial ability from childhood to adulthood and attempt to unveil the related secrets. Most prominent issue is spatial ability and age.

* Differential research

Focus of research is to determine the difference in spatial abilities across gender and other attributes. It also focused on analyzing the reasons behind the differential growth of spatial abilities among the different individuals. Issues such as impact of hormone on spatial ability, difference in spatial perception among male and female, impact of working memory capacity on spatial ability etc where also significant research areas of approach.

* Information processing research

Attempts to trace the flow of information through the human cognitive system from the time some stimulus is initially perceived to the time an over is taken. The major objective is to understand the cognitive processes, cognition and the rate and efficiency of cognitive processing. Predominant issues focused were the speed and efficiency in spatial processing and its impact on the development of spatial ability, strategies involved in solving spatial problems and the relationship between cognitive style and spatial ability.

* Applied research

It attempts to analyze the practical application of spatial ability in various academic and professional domains. Its major goal is to find out the predictive ability of spatial ability in achieving success in academic disciplines like engineering, mathematics, science and technology, and professions that require a knowledge and mastery of spatial skills. Spatial ability training and impact on the development of spatial skills also is a recent focus of this research approach.

**Review of Related Literatures**

**Mathematical Creativity**

Anjali S (2013) investigated the role of play schools with regard to the behavioral profile, creativity, problem solving ability and social cognition of preschoolers. The sample selected for the study was 300 preschoolers of whom 150 who had attended play school and remaining 150 who had not attended play school. The evaluation of the study gives a positive indication of the influence of play school on the behavioral profile creativity, problem solving ability and social cognition of preschoolers.

Betty P J (2013) executed a study on mathematical creativity and ability for fundamental mathematical operations of primary school students with dyscalculia. Sample consists of 2024 primary school students selected from 50 schools of Ernakulum district. The major conclusion of the study was among the selected primary school students an average of 6% is dyscalculic students. Dyscalculic and normal students differ significantly with respect to mathematical creativity and ability for fundamental operations and all their components.

Fousiya Kuveri (2013) studied about effectiveness of concept mapping on scientific creativity among secondary school students. The study was conducted on two groups of students of standard IX of two schools in Mankada sub district under Malappuram educational district. Findings of the study revealed that concept mapping is highly effective to develop scientific creativity.

Nicemol Sebastian (2013) conducted a study about relationship between mathematical creativity achievements in mathematics of secondary school pupils. The study conducted on 992 secondary school pupils. The tools used for the study was mathematical creativity test and achievement test in mathematics. The result of the study shows that there is significant positive relationship between the two variables mathematical creativity and achievement in mathematics.

Nisha S R (2010) conducted a study about the influence of commercialized learning materials for developing creativity in mathematics in secondary school students. The study was administrated on a sample of 607 students and 31 mathematics teachers from 7 districts of Kerala state. The results shows that even though opportunities are for the development of creativity in mathematics of secondary school students, the utilization of commercialized learning materials act as a barrier for the development of creativity in secondary school students.

Sreerekha R (2001) in her study investigated the relationship between self concept, intelligence mathematics creativity and achievement in mathematics of secondary school pupils. The findings of the study revealed that intelligence and mathematical creativity related positively and significantly with mathematics achievement.

Kavitha M (2009) conducted a study on interaction effect of mathematical creativity, intelligence and problem solving ability on achievement in mathematics of IX standard students of Bangalore district. The sample consists of 600 students of IX standard students studying in different types of English medium schools in Bangalore. It was found that there is significant positive relationship between mathematical creativity and achievement in mathematics.

Preethy E P (2008) investigated on the relative efficiency of problem solving ability, mathematical interest and awareness in the utility of mathematics in predicting achievement in mathematics of secondary school pupils of Kerala. The study was conducted on a sample of 500 students of IX drawn from 10 schools of Kozhikode and Malappuram districts of Kerala. It was found that the three predictor variables( problem solving ability, mathematics interest and awareness in the utility of mathematics) have significant positive correlation with achievement in mathematics.

Nifsa C (2007) attempt to study the interaction effect of creativity and formal reasoning on problem solving ability in physics of secondary school students. A total of 550 secondary school students from IXth standard selected as the sample for the study. The findings of the study reveal that there is a direct relationship between creativity and problem solving ability in physics. The study also reveals that formal reasoning influences problem solving.

Soumya U N (2007) conducted a study on the relationship between creative thinking and problem solving ability of IX standard students of Ernamkulm district. Sample of the study consist of 300 students of IX standard in Ernamkulam district. The study reveals that there exist a significant positive relationship between creative thinking and problem solving ability.

Soumya R S (2003) examined the interaction effect of creativity and intelligence on process outcomes in science of secondary school pupils of Malappuram district. Study was conducted on a representative sample of 500 students of secondary schools in Malappuram district. The findings reveal that the main effect of intelligence on creativity on process outcomes in science is significant.

Sunitha K (1997) investigated the creativity in relation to achievement in Malayalam of secondary school students. The study was conducted on a sample of 500 secondary school pupils. The study showed a significant difference exists in creativity between high and low achievers in Malayalam.

Resmi S (1997) attempt to find out the interaction effect of mathematics study approach and mathematical creativity on achievement in mathematics of secondary school pupils in Kerala. The study was conducted on 600 students of standard IX drawn from 3 districts of Kerala. Three tools were used by the investigator. Achievement test in Mathematics, Test of mathematical creativity, Mathematics study approach inventory. The findings of the study reveals that mathematics study approach has not too much to do with achievement in Mathematics of secondary school pupils when compared to the variable Mathematical Creativity. Even though both the variables mathematical creativity and mathematical study approach has significant main and interaction effect.

Dahiya S S (1995) investigated the effect of mastery learning strategy on pupil’s achievement in mathematics and their creative abilities using a sample of 70 pupils studying in seventh class of two different secondary schools Nangloi city in Delhi. The result of the study is that the group of pupils taught mathematics through mastery learning strategy has scored significantly higher on the criterion achievement test than the group of pupils taught mathematics through conventional method.

Usha Rani P (1994) conducted a study on the creativity of high school pupils in learning the English language. The study was conducted among 200 pupils of Thrissur educational district. She found a statistically significant correlation.

Syamala Devi (1993) examined the relationship of creativity with self concept and some selected sociological variables of standard IX pupils. The study was conducted on 700 students from Kozhikode, Wayanad, Kannur districts of Kerala State. The investigator found that even though socio economic status was insignificant in prediction creativity there exists a relationship among these variables.

Remadevy A (1993) aimed to find out the relationship between attitude towards science and creativity in science of secondary school pupils. The study was conducted on 704 secondary school pupils from different schools selected by stratified random sampling from three districts of Kerala. The result revealed that there exist a positive significant relationship between attitude towards science and creativity in science.

Anil Kumar V (1992) examined the relationship between creativity in science and certain demographic variables of secondary school pupils. Sample selected for the study was 700 pupils studying in IX standard from three districts of Kerala. The study reveals that there exists a positive relationship between the variables sex, locale, and socio economic status with creativity in science.

Sreekala C (1991) conducted a study on the effect of certain attitude variables and intelligence on creativity of secondary school pupils of Kerala. The study was conducted on a sample of 750 secondary school pupils. The major findings of the study are that the main effect of attitude towards mathematics, towards problem solving, towards education and intelligence on creativity is significant.

Chandini K S (1989) investigated on the efficiency of some social familial variables in predicting creativity. The sample selected for the study was 780 secondary school pupils from Ernamkulam and Thrissur districts of Kerala. The study revealed that the social familial variables home learning facility, family acceptance of education,family cultural level and family environment selected for the study was are poor in efficiency to predict creativity in its components like verbal creativity, figural creativity and symbolic creativity of secondary school pupils.

Symon Baby (1989) conducted a study to find out the relation of science interest and science learning environment with divergent thinking in science. Sample selected was 800 secondary schools from Trivandrum , Quilon, Pathanamthittta and Alappy. The findings of the study revealed that there is a significant positive relationship between science interest and divergent thinking in science.

**Spatial Ability**

Haresh Kumar B (2015) conducted a studyon construction and standardization of spatial reasoning ability test for the secondary school students.

Sunitha Krishnan (2014) conducted a study on spatial thinking skills in mathematics: A study among secondary school students. A sample of 100 students from IX standard following Kerala state syllabus of Ernakulum and Palakkad were selected. The result revealed that secondary school students have a lows level of spatial thinking skills. Girls are having a significantly high level of spatial thinking skills than boys and students from rural schools are having a significantly high of spatial thinking skills than students from urban schools.

Asha Paul (2011) executed a comparative study of Spatial Ability of Science and Humanities students of higher secondary schools in Kozhikode district. 600 higher secondary school of Kozhikode districts were selected as sample for the study. Tool used was ‘Mathew’s test of Mental Abilities (1973)’. The investigator could reach at the following conclusion that the level of Spatial Ability of Science students and Humanities students is only at an average level. There is no influence of gender, locale and type of management of school on the level of Spatial Ability of Science students and Humanities students.

Asitha R (2011) conducted a study on gender difference in spatial intelligence and mathematical achievement in spatial intelligence and mathematics achievement among secondary school students. Normative survey method was adopted for the study. The sample is 67 tenth standard students of Trivandrum district. The study reveals that there is no significant difference in spatial intelligence of boys and girls. Also there exists no significant difference between achievement and spatial ability among secondary school boys and girls.

Shakila J (2011) investigated learning of mathematical concepts in relation to spatial ability and problem solving skills among secondary school students. The sample taken for the study consists of 620 pupils from 31 schools of IX class in Krishna district. The major findings of the study was most of the pupils have average level of learning of mathematical concepts problem solving skill and spatial ability. But shows a positive relation between learning of mathematical concept, problem solving skill and spatial ability of secondary school students.

Ambili A (2008) made a study on gender quest in science with special reference to scientific aptitude among higher secondary school students of Kerala. The study was conducted on 485 higher secondary school students of Malappuram educational district. The tool used for the study is scientific aptitude test developed by the investigator. The components considered for the test are Number series, Science information, Spatial Ability, Verbal comprehension and interpretation. The findings of the study reveals that there is no significant difference in Science Aptitude based on the variable gender, locale of school and educational status of parents.

Roobina Sonia (2008) explored the achievement in mathematics of secondary level students of CBSE schools in relation to problem solving ability, spatial ability and achievement motivation. The study has been conducted on a representative sample4 of 525 CBSE school students of standard IX from Thiruvananthapuram district. The result shows that achievement in mathematics, problem solving ability, spatial ability and achievement motivation of secondary level students of CBSE schools are found to be generally high and they are invariably related to each other.

Asuthosh Thakar (2007) conducted a study about construction and standardization of spatial ability test for the pupils of higher secondary schools of Gujarat state. The test was administrated on 1827 pupils studying in different areas of different higher secondary schools of Gujarat.

Sooryachithra G (2005) investigated the relation of spatial ability and numerical reasoning on mathematics achievement of secondary school students. The conclusion obtained from this study is that the independent variables, spatial ability and numerical reasoning are clearly related to the dependant variable achievement in mathematics.

Jyothilekshmi J R (2004) conducted a comparative study of mathematical aptitude, spatial ability and mathematical ability of secondary school students studying in government aided and unaided institutions following state, CBSE, and ICSE syllabus.

Babylatha (1997) conducted a study to find out the relative efficiency of Abstract Reasoning and Spatial Ability to predict Biology achievement of secondary school students of Kerala. Sample was 600 pupils of standard VIII. Standardized differential aptitude tests of accepted levels of validity and reliability were used for measuring abstract reasoning and spatial ability. The result shows that Spatial Ability and Abstract Reasoning are highly related to Biology achievement.

**Conclusion**

The reviewing of related literature helped the investigator to know about the various studies conducted in the area of creativity and spatial ability. It helps the investigator to know about various tools used to measure the constructs and different components included in the preparation of the tools. Many studies are related on identification of creativity with other variables on various subjects. Most of the studies are conducted on the secondary level students. Studies related to spatial ability is very low when compared to creativity. No more studies are done in relation to mathematical creativity and spatial ability. The investigator was interested to know the influence of spatial ability on mathematical creativity of higher secondary school students. The investigator found that the study is relevant in the modern era and decided to proceed with the study. The procedure adopted for the present study is explained in chapter III.

**CHAPTER III**

**METHODOLOGY**

* ***Variables of the study***
* ***Objectives of the study***
* ***Hypothesis of the study***
* ***Tools used for data collection***
* ***Samples used for the study***
* ***Data collection procedure***
* ***Scoring and consolidation of data***
* ***Statistical techniques used for analysis***

**METHODOLOGY**

Methodology is a process which reveals all the methods and techniques followed by the researcher during the course of research work. The process of any research work depends largely up on the suitably of the methods, tools and techniques followed by the researcher in collecting and processing data. Thus the role of methodology is to carry on the research work in a scientific and valid manner.

 The present study is an attempt to find out the influence of spatial ability on mathematical creativity of higher secondary school students. The study was based on subsamples gender, board of school, subject specification.

Methodology of the study is presented below under the following heads viz;

1. Variables
2. Objectives
3. Hypothesis
4. Tools used for the study
5. Samples used for the study
6. Data collection procedure, Scoring and consolidation of data
7. Statistical techniques used for analysis

The details of each of the above are given below

**Variables**

The major objective of this study is to find out the extent of relationship between spatial ability and mathematical creativity of higher secondary school students. It includes two types of variables independent and dependent. The independent variable is spatial ability. Dependant variable is mathematical creativity.

**Objectives**

1. To find is there exists any significant relationship between spatial ability and mathematical creativity for the total sample.
2. To find is there exists any significant relationship between spatial ability and mathematical creativity for the sub samples based on
3. Gender
4. Board of education
5. Subject specifications
6. To find is there exists any significant difference in spatial ability for the sub samples based on
7. Gender
8. Board of education
9. Subject specifications
10. To find is there exists any significant difference in mathematical creativity for the sub samples based on
11. Gender
12. Board of education
13. Subject specifications

**Hypothesis**

1. There is no significant relationship between spatial ability and mathematical creativity for the total sample.
2. There is no significant relationship between spatial ability and mathematical creativity for the sub samples based on
	1. Gender
	2. Board of education
	3. Subject specifications
3. There is no significant difference in spatial ability for the sub samples based on
	1. Gender
	2. Board of education
	3. Subject specifications
4. There is no significant difference in mathematical creativity for the sub samples based on
	1. Gender
	2. Board of education
	3. Subject specifications

**Tools Used For the Study**

 Data collection is one of the major parts of the research process. For an effective data collection, an effective tool and technique has to be selected and necessary steps have to be taken in the preparation of the tool or the conduction of techniques was to be adopted. The tools or techniques may vary as per the complexity, design, administration and interpretation of the research.

For this study data were collected by using the following tools.

1. Mathematical Creativity Test ( Anees and Vijitha, 2015 )
2. Spatial Ability Test ( Anees and Vijitha, 2015 )

**Description of the Tool**

1. **Mathematical Creativity Test** ( Anees and Vijitha, 2015 )

 Mathematical Creativity Test for collecting the data regarding the Mathematical Creativity of higher secondary school students was prepared by the investigator with the help of the supervising teacher, experts in the field and mathematics teachers.

1. **Spatial Ability Test** ( Anees and Vijitha, 2015)

 The Spatial Ability Test for collecting the data regarding the Spatial Ability of higher secondary school students was prepared by the investigator with the help of the supervising teacher and experts in the field of education.

**Planning**

Good test do not just happen nor are they the result of a few moments of high inspiration and exaltation. On the contrary, the process is calm, deliberate and time consuming. The investigator initially considered various definitions available on the terms mathematical creativity and spatial ability and referred several books and journals in Mathematics, Psychology, Evaluation and Research Methodology and other resources to get details regarding test construction. The investigator consulted several experts in the field. From the various definitions and descriptions, the investigator analyzed and pooled a list of the components for each of the terms, which would comprehensively represent them as per their operational definitions given by the investigator.

From reviewing many studies related with Spatial Ability and Mathematical Creativity and also from discussion with the supervising teacher and other experts, the investigator developed a final list of relevant components for the preparation of the tool.

**Components of Mathematical Creativity**

The concept of divergent thinking by J.P.Guilford (1967) was selected as a base for the preparation for the present Mathematical Creativity Test. According to his theory Fluency, Flexibility, Originality, Elaboration, Redefinition, Sensitivity to problems are the components of the Creativity. It was decided to include the components Fluency, Flexibility, Originality and Sensitivity to problems for the development of Mathematical Creativity Tool.

**1. Fluency**

The term fluency according to J.P.Guilford is the Number of appropriate responses one can produce in limited time when told to produce a list of items of a certain kind.

Eg : *Write as many equations as possible using the symbols +, −, x, ÷, = and use the numbers 1, 3, 4, 5, 6 so as to get 18?*

**2. Flexibility**

Flexibility has been defined as a change of some kind, a change in meaning, interpretation or use of something, a change in understanding of some task, a change in strategy in doing the task or change in the direction of thinking which may mean new interpretation of the goal.

Eg*:* *Using the following bar diagram prepare as many questions and answers you can. The scores of four students in an achievement test are given.*

**3. Originality**

Originality means the ability to produce unusual or uncommon responses, remote associations or connections or clever responses. It indicated by the scores of some tests in which keyed responses are weighted in proportion to their infrequency of occurrence in the population examinees.

Eg*:* *Form mathematical shapes by joining adjacent points.*

**4. Sensitivity to problems**

It involves seeing defects, needs, deficiencies, seeing the odd, the unusual; seeing what must be done.

Eg: *Among some scores the smallest is 36 and the largest is 56 which of the following cannot be a mean of scores*

 *a) 39.4 b) 43*$\frac{1}{2}$ *c) 49 d) 60*

**Components of Spatial Ability**

Spatial ability stands for mental skills connected with spatial relationships. This involves ability for visualizing two dimensional drawings and perceives the three dimensional objects represented there and interpret certain relationships. For measuring this variable the following three components are considered.

**1. Spatial Visualization**

According to Mc Gee (1979) spatial visualization refers to ability to manipulate, rotate, and change the position in mind of an object depicted as picture.

* Ability to visualize a configuration in which there is movement among its parts.
* Ability to comprehend imaginary movements in three dimensions and to manipulate objects in imagination.
* Ability to manipulate or transform the image of a spatial pattern to other arrangements.

Eg: *Which one of the following figures A, B, C, D will be the right choice if we arrange the first figure in a proper manner?*

 **A B C D**

**2. Spatial Orientation**

According to Mc Gee (1979) spatial orientation refers to the

* Ability to determine relationships between different spatial objects.
* Ability to recognize the identity of an object when it is seen from different angles or when the object is moved.
* Ability to consider spatial relations where the body orientation of the observer is essential.
* Ability to perceive spatial patterns and to compare them with each other.
* Ability to remain unconfused by the varying orientation in which spatial object may be presented

Eg: *Count the number of BLOCKS in the shape?*

**14**

**12**

**20**

**10**

A B C D

**3. Mental Rotation**

 According to Linn and Peterson (1985) Mental Rotation refers to the ability to determine the new projection of a 2D or 3D object which has been rotated from a certain position.

Eg*: Which one is identical to the first if we rotate the first figure?*

 **A B C D**

**Preparation**

 The review of related literature helps the investigator to construct items for the Mathematical Creativity Test and Spatial Ability Test. For ensuring the content validity of the test, the investigator collected the important components of creativity from different sources, literature and with the help of supervising teacher and discussion with the experts in the concerned area. Based on the above mentioned components the investigator developed mathematical creativity test and spatial ability test.

Both tests are administrated to the same sample to collect data for the present study. Generally students are not patient enough to attend long tests. It is found that shorter the tests, the higher the number of subjects completing the test. Also each question in the mathematical creativity requires more span of time. Taking these into consideration it was decided to conduct a test which would serve the purpose of measuring mathematical creativity of higher secondary school students only having 13 questions and spatial ability test having 30 questions.

 The test items were selected based on the following principles.

* Suitable for the cognitive level of students.
* Related to the physical and social environment of the learner.
* Motivating for imaginative insights.
* Helpful for promoting critical thinking.
* Easy to score.
* Presented in unambiguous terms.
* Accessible to learners with minimum instruction.
* Simple and proper length to avoid fatigue and boredom.

**Mathematical Creativity Test**

Out of 13 questions in the Mathematical Creativity Test 7 items are scored for fluency, flexibility and originality. Therefore these items receive three scores and the sum of these three scores calculated as the score for that item. The remaining 5 items intended to measure the component sensitivity to the problems. It was provided with choices and correct answer will get 1 score. The sum of scores of all the items of the test is taken as the total mathematical creativity score of the pupils. The time allotted for Mathematical Creativity Test was 40 minutes.

Details of the items are shown below

Table 1

*Details of Mathematical Creativity Test items*

|  |  |  |  |
| --- | --- | --- | --- |
| SI.NO | Components  | Item Numbers | Total Number of Items |
| 1 | Fluency | 1, 2, 3,4, 5,6, 12, 13 |  7 |
| 2 | Flexibility |
| 3 | Originality |
| 4 | Sensitivity to problems | 7, 8, 9, 10, 11 |  5 |
|  TOTAL |  13 |

Copy of Mathematical Creativity Test was given in Appendix I.

**Spatial Ability Test**

Spatial Ability Test consists of 30 items. It was based on the three components spatial visualization, spatial orientation and mental rotations. For measuring spatial visualization 12 items are included in the test. This test items are used to measure how quickly and accurately one can think. In each problem a key figure is given, followed by some figures. The key figure when arranged in a particular manner gives one of the figures A, B, C; D. the subject taking the test has to decide which of the figure A, B, C, and D can be generated from the key figure. Response has to make by putting $ '√'$ in the circle given under the letters A, B, C, and D in the separate answer sheet.

For measuring spatial orientation 10 items are included in the test. The test item consist of a two dimensional arrangement of blocks of the same size and shape. The subject is to estimate the total number of blocks (both visible and invisible) represented in the pile. From the four answers given the subject has to encircle the correct answer.

8 items are intended to measure mental rotation. Test items presented diagrammatically. In each problem a key figure is given, followed by a row of figures. Among the figures some can be generated from the key figure by rotating it in their direction. But certain figures in the series cannot be obtained by such rotations, since they are mirror images of the key figure. The subject taking the test has to decide which of the figures given A, B, C, and D can be generated by the key figure. The time allotted for Spatial Ability test was 40 minutes.

Table 2

*Details of Spatial Ability Test items*

|  |  |  |  |
| --- | --- | --- | --- |
| SI NO: | Components | Item Numbers | Number of Items |
|  1 | Spatial visualization | 1,2,3,4,5,6,7,8,9,10,27,28 |  12 |
|  2 | Spatial Orientation  | 11,12,13,14,15,16,23,24,25,26 |  10 |
|  3 | Mental Rotation | 17,18,19,20,21,22,29,30 |  8 |
|  TOTAL |  30 |

Copy of Spatial Ability Test was given in Appendix II.

**Validity**

An index of validity shows the degree to which a test measures what intends to measure when compared with accepted criterion. Validity as the quality of a data gathering instrument or procedure that ensures to measure what is supposed to measure (Best & Kahn, 2009).

The validity of the present tests was ensured using face validity and content validity. For Mathematical Creativity Test in addition to these two construct validity is also ensured.

A test is said to have face validity when it appears to measure whatever the author had in mind, namely what he thought he was measuring (Garette, 2005). The items in the present tests were phrased in the least ambiguous way and meanings of all the terms were clearly defined. After preparing the items the investigator consulted expert teacher educators and mathematics teachers to examine the validity of the test and its validity has got established.

For ensuring the content validity of the tests the investigator collected the important components of Mathematical Creativity and Spatial Ability from different sources such as literatures, journals, related books with the help of supervising teachers and discussion with the experts.

Construct validity of the research concerns the question of whether the result supports the theory behind the research. The test has validity as it is prepared on the procedure of construction of creativity test by Guilford.

**Samples Used For the Study**

The selection of proper samples determines the reliability and validity of the results obtained. If a sampling is not correctly designed and followed, sampling errors may affect findings. Therefore, the prime concern in the selection of a sample is to assure its representativeness.

The present study conducted on a representative sample of 400 higher secondary school students of Malappuram and Kozhikode district. The sample was selected using stratified random sampling technique giving due representation to different strata viz;

1. Gender
2. Board of education
3. Subject specification
4. **Gender**

The cognitive abilities and other characteristics may be different in Boys and Girls. Hence the investigator included equal proportion of Boys and Girls.

1. **Board of education**

Learning experiences are different in different Boards of Education. The present study considers two boards of education viz; Kerala State Education Board and CBSE.

1. **Subject specification**

Subject specification is categorized in to two. They are Science and commerce. Both subjects need Mathematical Creativity.

The details of strata wise sampling size is given in table 3.

Table 3

*Details of the final sample*

|  |  |  |  |
| --- | --- | --- | --- |
|  Sub Sample |  Gender | Board of education | Subject specification |
|  | Male | Female | State | CBSE | Science | Commerce |
|  200 |  200 |  240 |  160 |  200 |  200 |
|  TOTAL |  400 |  400 |  400 |

Details of the schools visited for data collection are given in table 4.

Table 4

*Details of the schools visited for data collection*

|  |  |  |  |
| --- | --- | --- | --- |
| SI NO | Name of School | State/CBSE | District |
|  1 | MVHSS Ariyallur | State | Malappuram |
|  2 | BEMHSS Parappanangadi | State | Malappuram |
|  3 | CBHSS Vallikkunnu | State | Malappuram |
|  4 | Sree Valluvanad VidyaBhavan Senior SecondarySchool, Perinthalmanna | CBSE | Malappuram |
|  5 | MES Central School, Tirur | CBSE | Malappuram |
|  6 | GVHSS Thamarassery | State | Kozhikode |
|  7 | GHSS Karuvanpoyil | State | Kozhikode |
|  8 | Govt Ganapath Higher Secondary School,Feroke | State | Kozhikode |
|  9 | Bharathiya Vidya Bhavan,Chevayur | CBSE | Kozhikode |
| 10 | Al Haramain English School, Kunduparamba | CBSE | Kozhikode |

**Administration of the tool**

After the sample selection the investigator prepared time schedule for visiting the schools for data collection the investigator approached the heads of the concerned institutions for obtaining permission for data collection. Before administration the investigator gives necessary instructions and carefully clarified the doubts of the students, when the test administration was over, the investigator collected back the answer sheets and question booklets.

**Scoring and Consolidation of Data**

**Scoring scheme for Mathematical Creativity Test**

The mathematical creativity test has been mainly scored for four components Fluency, Flexibility, Originality, and Sensitivity to problems.

**Fluency Score**: For each item the relevant responses are counted and each response is assigned 1 score. Those repeated in an identical form are excluded. The total scores from all the items is the total fluency score of an individual.

**Flexibility Score**: The responses are classified into categories and 1 score is assigned for each category. No additional score is assigned for more than one response in a category.

**Originality Score**: It is based on different degrees of uncommonness of the response as shown in Table 5.

Table 5

*Scoring scheme for originality*

|  |  |  |
| --- | --- | --- |
| No: | Grouping in terms of uncommonness of response | Scores |
| 1 | Responses given by less than 10% in the sample | 5 |
| 2 | Responses given by 10% to 15% in the sample | 4 |
| 3 | Responses given by 15% to 20% in the sample | 3 |
| 4 | Responses given by 20% to 25% in the sample | 2 |
| 5 | Responses given by 25% to 30% in the sample | 1 |
| 6 | Responses given by more than 30% in the sample | 0 |

**Sensitivity to problem score**: The items are provided with choices. Each correct answer will get 1 score and wrong answer will get zero score.

**Scoring scheme for Spatial Ability Test**

This test consists of 30 items. A score 1 is assigned to the correct response and ‘0’ for others. The sum of scores obtained for each 30 questions will give a measure of Spatial Ability.

 Response sheets were scored according to the scoring procedure and were consolidated and tabulated for further statistical analysis. The maximum and minimum score of Mathematical Creativity Test were 77 and 25 respectively. The maximum and minimum score of Spatial Ability Test were 27 and 7 respectively.

 The answer sheet of Spatial Ability Test and Answer key for the Spatial Ability Test are included in the Appendix III and Appendix IV respectively.

**Statistical Techniques Used For Analysis of Data**

The raw scores obtained for the test of Mathematical Creativity and Spatial Ability among 400 higher secondary school students were subjected to statistical treatment.

 Statistical techniques used for the analysis of the data are the following

**1. Preliminary analysis**

Preliminary analysis was done in order to arrive at a conclusion about the nature of the distribution. Preliminary analysis involves the following statistical techniques

1. Measures of Central Tendency
2. Standard Deviation
3. Skewness
4. Kurtosis

**2. Pearson’s Product Moment Coefficient of Correlation (r)**

The most often used and precise coefficient of correlation is Pearson’s Product Moment Coefficient of Correlation. The degree of relationship is measured and represented by coefficient of correlation.

 r =$ \frac{N∑XY-∑X∑Y}{\sqrt{[N∑X^{2}-\left(∑X\right)^{2}][N∑Y^{2}-\left(∑Y\right)^{2}]}}$

Where,

$∑X$ = Sum of X scores

$∑Y$ = Sum of Y scores

$∑XY$ = Sum of the product of X and Y scores

$∑X^{2}$ = Sum of squares of X scores

$∑Y^{2}$ = Sum of squares of Y scores

$N$ = Number of scores

 The value of **‘r’** obtained is described in terms of

* Magnitude of **‘r’**.
* Direction of **‘r’**.
* Statistical significance of the coefficient.$ $

**Interpretation of Computed Correlation Coefficient**

The computed correlation coefficient between two variables is then interpreted to find whether there exists any correlation between the two variables and if any such relation exists, how far the relation is significant. The interpretation of correlation coefficient is presented in Table 6.

Table 6

*Interpretation of correlation coefficient*

|  |  |
| --- | --- |
| Range of Computed Correlation |  Interpretation  |
| 0 | Zero correlation, absolutely no relationship |
| 0.0 to ± 0.2 | Slight; almost negligible relationship |
| ±0.21 to ± 0.4 | Low correlation; definite, but small relationship |
| ±0.41 to ± 0.6 | Moderate relation; substantial, but small relationship |
| ±0.61 to ± 0.8 | High correlation; marked relationship |
| ±0.81 to ± 0.99 | Very high correlation |
| ±1 | Perfect correlation; almost identical or opposite relationship |

In this study correlation coefficient ‘r’ is used to find out the extent of relationship between Mathematical Creativity and Spatial Ability of higher secondary school students.

1. **Test of Significance of Difference between Means for Different Categories**

Thestatistical techniques “Test of Significance of Difference between Means for Different Categories” was used to find out if there exists any significant difference in Mathematical Creativity and Spatial Ability between relevant sub samples.

The Test of Significance of Difference Between Means for Different Categories is known as **‘t’** test. The tabled value for 0.01 level of significance is 2.58 and the tabled value for 0.05 level of significance is 1.96.

 t = $\frac{\overline{X\_{1}}-\overline{X\_{2}}}{\sqrt{\frac{σ\_{1}^{2}}{N\_{1}}+\frac{σ\_{2}^{2}}{N\_{2}}}}$

$\overline{X\_{1}}$ = Mean of the Group I

$\overline{X\_{2}}$ = Mean of the Group II

$σ\_{1}$ = Standard deviation of the Group I

$σ\_{2}$ = Standard deviation of the Group II

$N\_{1}$ = Sample size of the Group I

$N\_{2}$ = Sample size of the Group II

 If obtained critical ratio is greater than the required value for significance the mean difference is considered to be significant.

**CHAPTER IV**

**ANALYSIS AND INTERPRETATION OF DATA**

* ***Objectives of the study***
* ***Hypothesis of the study***
* ***Preliminary analysis***
* ***Correlation analysis for the total sample and sub samples***
* ***Comparison of mean scores of Spatial Ability and Mathematical Creativity of relevant sub samples***

**ANALYSIS AND INTERPRETATION OF DATA**

The present study is to assess the influence of Spatial Ability on Mathematical Creativity of higher secondary school students. This chapter deals with analysis and interpretation of data as per the following objectives.

**Objectives**

1. To find is there exists any significant relationship between spatial ability and mathematical creativity for the total sample.
2. To find is there exists any significant relationship between spatial ability and mathematical creativity for the sub samples based on
3. Gender
4. Board of education
5. Subject specifications
6. To find is there exists any significant difference in spatial ability for the sub samples based on
7. Gender
8. Board of education
9. Subject specifications
10. To find is there exists any significant difference in mathematical creativity for the sub samples based on
11. Gender
12. Board of education
13. Subject specifications

**Hypothesis**

1. There is no significant relationship between spatial ability and mathematical creativity for the total sample.
2. There is no significant relationship between spatial ability and mathematical creativity for the sub samples based on
	1. Gender
	2. Board of education
	3. Subject specifications
3. There is no significant difference in spatial ability for the sub samples based on
	1. Gender
	2. Board of education
	3. Subject specifications
4. There is no significant difference in mathematical creativity for the sub samples based on
	1. Gender
	2. Board of education
	3. Subject specifications

**Preliminary Analysis of Test Scores**

 A preliminary analysis of the scores of independent variable and dependant variable of the present study was done to know the basic properties for the total sample and subsamples based on gender, board of education, subject specifications. The important statistical properties like Mean, Median, Mode, Standard Deviation, Skewness, Kurtosis were computed for the whole sample. The details of the statistics are presented in Table 7.

Table 7

*Preliminary analysis of the test scores*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Variable | N | Mean | Median | Mode | Standard Deviation | Skewness | Kurtosis |
| MathematicalCreativity | 400 | 49.29 | 47.50 | 45 | 14.61 | 0.174 | 1.07 |
| Spatial Ability | 400 | 17.96 | 18 | 16 | 5.47 | -0.20 | 0.93 |

 The important statistical constants of the selected variables for the total sample and subsample were analyzed. The measures like Mean, Median, Mode, Standard Deviation, Skewness and Kurtosis were computed for the whole sample.

For the variable Mathematical Creativity, the values of Median and Mode are almost equal and Mean is greater than Median and Mode. The extent of Skewness or index of asymmetry is 0.174 which shows the distribution is positively skewed. The measure of Kurtosis is 1.07 which shows the distribution is leptokurtic. For the variable Spatial Ability, the value of Mean is in between Median and Mode, and they are almost equal. The extent of Skewness or index of asymmetry is -0.20 which shows the distribution is negatively skewed. The measure of Kurtosis is 0.93 which shows the distribution is leptokurtic.

 The distribution was further examined using P-P plot (Probability-Probability). This graph plots the cumulative probability of a variable against the cumulative probability of normal distribution. What this means is that the data are ranked sorted. Then for each rank the corresponding z- score is calculated. This is the expected value that the score should have in normal distribution. Next the score itself is converted to a z-score. The actual z- score is plotted against the expected z- score. If the data are normally distributed then the actual z- score will be the same as the expected z- score and will get a straight diagonal line, but deviations from the diagonal show deviation from normality.



*Figure 4***:** Normal probability- probability plot of Mathematical creativity for the total sample.



*Figure 5*: Normal probability- probability plot of Spatial Ability for the total sample.

The normal P-P Plot revealed that there is only a slight variation of observed cumulative probability from the diagonal. So the distribution is approximated to normality. The near normal distribution obtained suggests that the sample chosen for the present study is fairly representative of the population.

**Major Analysis**

1. Pearson’s product moment coefficient of correlation(r)
2. Test of significance of mean difference for large independent sample (t-test).

**The Extent of Relationship between Spatial Ability and Mathematical Creativity of Higher Secondary School Students**

The collected data has been analyzed to find out the extent of relationship between Spatial Ability and Mathematical Creativity of Higher Secondary School Students. It is estimated using Pearson’s Product Moment Coefficient of correlation(**r**). The investigator could use Pearson’s Product Moment Coefficient of Correlation as all the variables involved in the study are continuous and of interval type measurement. As all the assumptions are satisfied the investigator proceeded with the computation Pearson’s ‘**r’**.

Table 8

*Coefficient of Correlation between Spatial Ability and Mathematical Creativity of Higher Secondary School Students*

|  |  |  |
| --- | --- | --- |
| sample | category | Correlation |
| Total | ------ | 0.756 |
| Gender | Male | 0.832 |
|  | Female | 0.680 |
| Board of education | Kerala State education board | 0.756 |
|  | CBSE | 0.760 |
| Subject specifications | Science  | 0.745 |
|  | commerce | 0.768 |

 The table 8 shows the Coefficient of Correlation between Spatial Ability and Mathematical Creativity of Higher Secondary School Students in the total sample and sub samples based on Gender, Board of education, Subject specification.

 The coefficient of correlation obtained for the total sample is 0.756. The value obtained suggests that the relation between the variable is significant at 0.01 level as the ‘r’ is greater than the tabled value required for significance at 0.01 level. The magnitude and direction of ‘r’ indicate the existence of high and marked positive relationship between variables. Hence it can be concluded that there exists significant high and positive relationship between the variables Spatial Ability and Mathematical Creativity for the total sample.

 The coefficient of correlation obtained for the male higher secondary school students is 0.832. The value obtained suggests that the relation between the variable is significant at 0.01 level as the ‘r’ is greater than the tabled value required for significance at 0.01 level. The magnitude and direction of ‘r’ indicate the existence of very high and positive relationship between variables. Hence it can be concluded that there exists significant very high and positive relationship between the variables Spatial Ability and Mathematical Creativity of male higher secondary school students.

 The coefficient of correlation obtained for the female higher secondary school students is 0.680. The value obtained suggests that the relation between the variable is significant at 0.01 level as the ‘r’ is greater than the tabled value required for significance at 0.01 level. The magnitude and direction of ‘r’ indicate the existence of high and positive relationship between variables. Hence it can be concluded that there exists significant high and positive relationship between the variables Spatial Ability and Mathematical Creativity of female higher secondary school students.

 The coefficient of correlation obtained for Kerala state syllabus higher secondary school students is 0.756. The value obtained suggests that the relation between the variable is significant at 0.01 level as the ‘r’ is greater than the tabled value required for significance at 0.01 level. The magnitude and direction of ‘r’ indicate the existence of high and positive relationship between variables. Hence it can be concluded that there exists significant high and positive relationship between the variables Spatial Ability and Mathematical Creativity of Kerala state syllabus higher secondary school students.

 The coefficient of correlation obtained for CBSE syllabus higher secondary school students is 0.760. The value obtained suggests that the relation between the variable is significant at 0.01 level as the ‘r’ is greater than the tabled value required for significance at 0.01 level. The magnitude and direction of ‘r’ indicate the existence of high and positive relationship between variables. Hence it can be concluded that there exists significant high and positive relationship between the variables Spatial Ability and Mathematical Creativity of CBSE higher secondary school students.

 The coefficient of correlation obtained for the higher secondary school science students is 0.745. The value obtained suggests that the relation between the variable is significant at 0.01 level as the ‘r’ is greater than the tabled value required for significance at 0.01 level. The magnitude and direction of ‘r’ indicate the existence of high and positive relationship between variables. Hence it can be concluded that there exists significant high and positive relationship between the variables Spatial Ability and Mathematical Creativity of higher secondary school science students.

 The coefficient of correlation obtained for the higher secondary school commerce students is 0.768. The value obtained suggests that the relation between the variable is significant at 0.01 level as the ‘r’ is greater than the tabled value required for significance at 0.01 level. The magnitude and direction of ‘r’ indicate the existence of high and positive relationship between variables. Hence it can be concluded that there exists significant high and positive relationship between the variables Spatial Ability and Mathematical Creativity of higher secondary school commerce students.

**Discussion**

 The coefficient of correlation between Spatial Ability and Mathematical Creativity of higher secondary school students were analyzed. Results show that there exists a significant high and positive relationship between variables Spatial Ability and Mathematical Creativity for the total sample. It is evident from the results that there is a high tendency in the variable Mathematical Creativity to be increased when there is an increase in the Spatial Ability and vice versa.

 The coefficient of correlation between Mathematical Creativity and Spatial Ability of male higher secondary school students show that there is a significant very high relation between the variables Mathematical Creativity and Spatial Ability. It is evident from the results that the change in the one variable brings change in the other variable.

 The coefficient of correlation between Spatial Ability and Mathematical Creativity of female higher secondary school students show that there exists a significant high and positive relationship between Spatial Ability and Mathematical Creativity. It is evident from the results that there is a high tendency for the variable Mathematical Creativity to be increased when there is an increase in the Spatial Ability and vice versa.

 The coefficient of correlation between Spatial Ability and Mathematical Creativity of Kerala state syllabus higher secondary school students show that there exists a significant high and positive relationship between Spatial Ability and Mathematical Creativity. It is evident from the results that there is a high tendency for the variable Mathematical Creativity to be increased when there is an increase in the Spatial Ability and vice versa.

 The coefficient of correlation between Spatial Ability and Mathematical Creativity of CBSE higher secondary school students show that there exists a significant high and positive relationship between Spatial Ability and Mathematical Creativity. It is evident from the results that there is a high tendency for the variable Mathematical Creativity to be increased when there is an increase in the Spatial Ability and vice versa.

 The coefficient of correlation between Spatial Ability and Mathematical Creativity of higher secondary school science students show that there exists a significant high and positive relationship between Spatial Ability and Mathematical Creativity. It is evident from the results that there is a high tendency for the variable Mathematical Creativity to be increased when there is an increase in the Spatial Ability and vice versa.

 The coefficient of correlation between Spatial Ability and Mathematical Creativity of higher secondary school commerce students show that there exists a significant high and positive relationship between Spatial Ability and Mathematical Creativity. It is evident from the results that there is a high tendency for the variable Mathematical Creativity to be increased when there is an increase in the Spatial Ability and vice versa.

**Comparison of the Mean Scores of Spatial Ability and Mathematical Creativity of Higher Secondary School Students Based on Subsamples Gender, Board of Education and Subject Specification.**

The collected data has been analyzed to find out is there exists any significant difference in Mathematical Creativity and Spatial Ability based on subsamples gender, board of education and subject specification. The investigator could use the test of significance of difference between means (t-test) for large independent sample as all the variables involved in the study are continuous and of interval type measurement. As all the basic assumptions are satisfied the investigator proceeded with test of significance of difference between means (t-test).

**Comparison of Mean Scores of Spatial Ability between Male and Female Higher Secondary School Students**

Inthis analysis the investigator compared the difference for significance between male and female higher secondary school students in Spatial Ability. Comparison of total mean scores of Spatial Ability between male and female higher secondary school students was done. The result obtained is presented in table 9.

Table 9

*Data and Results of the Test of Significance of Difference in Spatial Ability between Male and Female Higher Secondary School Students*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| SI.NO | Category | N | Mean | SD | ‘t’ Value | Level of significance |
| 1 | Male | 200 | 18.09 | 5.43 | 0.475 | NS |
| 2 | Female | 200 | 17.83 | 5.53 |

From the table 9, it is found that the mean scores of Spatial Ability obtained for male and female higher secondary school students are 18.09 and 17.83 respectively. The standard deviation obtained is 5.43 and 5.53 respectively. The calculated ‘t’ value is 0.475. The table value of‘t’ at 0.01 level of significance is 2.58. Since the calculated ‘t’ value is less than the tabled value, it can be inferred that there is no significant difference in Spatial Ability between male and female higher secondary school students.

**Discussion**

 The analysis of the above data shows that there is no significant difference in Spatial Ability between male and female higher secondary school students. Hence it can be concluded that the male and female students does not differ in the level of Spatial Ability.

**Comparison of Mean Scores of Spatial Ability between Kerala State syllabus and CBSE syllabus Higher Secondary School Students**

Inthis analysis the investigator compared the difference for significance between Kerala State syllabus and CBSE syllabus higher secondary school students in Spatial Ability. Comparison of total mean scores of Spatial Ability between Kerala State syllabus and CBSE syllabus higher secondary school students was done. The result obtained is presented in table 10.

Table 10

*Data and Results of the Test of Significance of Difference in Spatial Ability between Kerala State syllabus and CBSE syllabus Higher Secondary School Students*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| SI.NO | Category | N | Mean | SD | ‘t’ Value | Level of significance |
| 1 | State | 240 | 17.55 | 5.46 | 1.85 | NS |
| 2 | CBSE | 160 | 18.58 | 5.45 |

From the table 10, it is found that the mean scores of Spatial Ability obtained for Kerala State and CBSE Higher Secondary School Students are 17.55 and 18.58 respectively. The standard deviation obtained is 5.46 and 5.45 respectively. The calculated ‘t’ value is 1.85. The table value of‘t’ at 0.01 level of significance is 2.58. Since the calculated ‘t’ value is less than the tabled value, it can be inferred that there is no significant difference in Spatial Ability between Kerala State and CBSE higher secondary school students.

**Discussion**

 The analysis of the above data shows that there is no significant difference in Spatial Ability between State and CBSE higher secondary school students. Hence it can be concluded that the State and CBSE students does not differ in the level of Spatial Ability.

**Comparison of Mean Scores of Spatial Ability between Higher Secondary School Science and Commerce Students**

Inthis analysis the investigator compared the difference for significance between higher secondary school science and commerce students in Spatial Ability. Comparison of total mean scores of Spatial Ability between higher secondary school science and commerce students was done. The result obtained is presented in table 11.

Table 11

*Data and Results of the Test of Significance of Difference in Spatial Ability between Higher Secondary School Science and Commerce Students*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| SI.NO | Category | N | Mean | SD | ‘t’ Value | Level of significance |
| 1 | Science | 200 | 17.93 | 5.52 | 0.128 | NS |
| 2 | Commerce | 200 | 17.80 | 5.44 |

From the table 11, it is found that the mean scores of Spatial Ability obtained for higher secondary school science and commerce students are 17.93 and 17.80 respectively. The standard deviation obtained is 5.52 and 5.44 respectively. The calculated ‘t’ value is 0.128. The table value of ‘t’ at 0.01 level of significance is 2.58. Since the calculated ‘t’ value is less than the tabled value, it can be inferred that there is no significant difference in Spatial Ability between higher secondary school science and commerce students.

**Discussion**

 The analysis of the above data shows that there is no significant difference in Spatial Ability between higher secondary school science and commerce students. Hence it can be concluded that the Science and Commerce students does not differ in the level of Spatial Ability.

**Comparison of Mean Scores of Mathematical Creativity between Male and Female Higher Secondary School Students**

Inthis analysis the investigator compared the difference for significance between male and female higher secondary school students in Mathematical Creativity. Comparison of total mean scores of Mathematical Creativity between male and female higher secondary school students was done. The result obtained is presented in table 12.

Table 12

*Data and Results of the Test of Significance of Difference in Mathematical Creativity between Male and Female Higher Secondary School Students*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| SI.NO | Category | N | Mean | SD | ‘t’ Value | Level of significance |
| 1 | Male | 200 | 49.36 | 14.81 | 0.106 | NS |
| 2 | Female | 200 | 49.20 | 14.83 |

 From the table 12, it is found that the mean scores of Mathematical Creativity obtained for male and female higher secondary school students are 49.36 and 49.20 respectively. The standard deviation obtained is 14.81 and 14.83 respectively. The calculated ‘t’ value is 0.106. The table value of ‘t’ at 0.01 level of significance is 2.58. Since the calculated ‘t’ value is less than the tabled value, it can be inferred that there is no significant difference in Mathematical Creativity between male and female higher secondary school students.

**Discussion**

 The analysis of the above data shows that there is no significant difference in Mathematical Creativity between male and female higher secondary school students. Hence it can be concluded that the male and female students does not differ in the level of Mathematical Creativity.

**Comparison of Mean Scores of Mathematical Creativity between Kerala State syllabus and CBSE syllabus Higher Secondary School Students**

Inthis analysis the investigator compared the difference for significance between Kerala state syllabus and CBSE syllabus higher secondary school students in Mathematical Creativity. Comparison of total mean scores of Mathematical Creativity between Kerala State syllabus and CBSE syllabus higher secondary school students was done. The result obtained is presented in table 13.

Table 13

*Data and Results of the Test of Significance of Difference in Mathematical Creativity between Kerala State syllabus and CBSE syllabus Higher Secondary School Students*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| SI.NO | Category | N | Mean | SD | ‘t’ Value | Level of significance |
| 1 | State | 240 | 48.96 | 14.30 | 0.543 | NS |
| 2 | CBSE | 160 | 49.77 | 15.10 |

From the table 13, it is found that the mean scores of Mathematical Creativity obtained for Kerala State and CBSE higher secondary school students are 48.96 and 49.77 respectively. The standard deviation obtained is 14.30 and 15.10 respectively. The calculated ‘t’ value is 0.543. The table value of ‘t’ at 0.01 level of significance is 2.58. Since the calculated ‘t’ value is less than the tabled value, it can be inferred that there is no significant difference in Mathematical Creativity between Kerala State and CBSE higher secondary school students.

**Discussion**

 The analysis of the above data shows that there is no significant difference in Mathematical Creativity between Kerala State and CBSE higher secondary school students. Hence it can be concluded that the Kerala State and CBSE students does not differ in the level of Mathematical Creativity.

**Comparison of Mean Scores of Mathematical Creativity between Higher Secondary School Science and Commerce Students**

Inthis analysis the investigator compared the difference for significance between higher secondary school science and commerce students in Mathematical Creativity. Comparison of total mean scores of Mathematical Creativity between higher secondary school science and commerce students was done. The result obtained is presented in table 14.

Table 14

*Data and Results of the Test of Significance of Difference in Mathematical Creativity between Higher Secondary School Science and Commerce Students*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| SI.NO | Category | N | Mean | SD | ‘t’ Value | Level of significance |
| 1 | Science | 200 | 49.28 | 14.41 | 0.003 | NS |
| 2 | Commerce | 200 | 49.29 | 14.84 |

From the table 14, it is found that the mean scores of Mathematical Creativity obtained for higher secondary school science and commerce students are 49.28 and 49.29 respectively. The standard deviation obtained is 14.41 and 14.84 respectively. The calculated ‘t’ value is 0.003. The table value of ‘t’ at 0.01 level of significance is 2.58. Since the calculated ‘t’ value is less than the tabled value, it can be inferred that there is no significant difference in Mathematical Creativity between higher secondary school science and commerce students.

**Discussion**

 The analysis of the above data shows that there is no significant difference in Mathematical Creativity between higher secondary school science and commerce students. Hence it can be concluded that the science and commerce students does not differ in the level of Mathematical Creativity.

**Conclusion**

Data collected from various schools were analyzed on the basis of the objectives of the study and interpreted in a meaningful way. Analysis and interpretation of data has resulted that there is a significant positive relationship between the variables Mathematical Creativity and Spatial Ability for the total sample and subsample based on gender, board of education and subject specification. The study also revealed that there is no significant difference in Mathematical Creativity and Spatial Ability based on the subsamples gender, board of education and subject specifications.

 The analysis and interpretation of data made here helped the investigator to draw various conclusions and put forward some suggestions for further study.

**CHAPTER V**

**SUMMARY, FINDINGS AND SUGGESTIONS**

* ***Study in retrospect***
* ***Variables***
* ***Objectives***
* ***Hypothesis***
* ***Methodology***
* ***Major findings***
* ***Tenability of Hypothesis***
* ***Educational Implications***
* ***Suggestions for the further study***

**SUMMARY, FINDINGS AND SUGGESTIONS**

This chapter high lights the significant aspect of the various stages of the study. This includes the summary of the procedure, important findings of the study, educational implications and suggestions for further research.

**Study in Retrospect**

The various aspects related to the present study like the variables, objectives, hypothesis and methodology are following in brief.

**Restatement of the Problem**

The present investigation was entitled as “Influence of Spatial Ability on Mathematical Creativity of Higher Secondary School Students in Kerala”.

**Variables**

The major objective of this study is to find out the extent of relationship between spatial ability and mathematical creativity of higher secondary school students. It includes two types of variables independent and dependent. The independent variable is spatial ability with components spatial visualization, spatial orientation and mental rotation. Dependant variable is mathematical creativity with components fluency, flexibility, originality and sensitivity to problems.

**Objectives**

1. To find is there exists any significant relationship between spatial ability and mathematical creativity for the total sample.
2. To find is there exists any significant relationship between spatial ability and mathematical creativity for the sub samples based on
3. Gender
4. Board of education
5. Subject specifications
6. To find is there exists any significant difference in spatial ability for the sub samples based on
7. Gender
8. Board of education
9. Subject specifications
10. To find is there exists any significant difference in mathematical creativity for the sub samples based on
11. Gender
12. Board of education
13. Subject specifications

**Hypothesis**

1. There is no significant relationship between spatial ability and mathematical creativity for the total sample.
2. There is no significant relationship between spatial ability and mathematical creativity for the sub samples based on
	1. Gender
	2. Board of education
	3. Subject specifications
3. There is no significant difference in spatial ability for the sub samples based on
	1. Gender
	2. Board of education
	3. Subject specifications
4. There is no significant difference in mathematical creativity for the sub samples based on
	1. Gender
	2. Board of education
	3. Subject specifications

**Methodology**

 It deals with the precise description of the sample used for the study, tools and statistical techniques used.

**Sample**

 The present study conducted on a representative sample of 400 higher secondary school students of Malappuram and Kozhikode district. The sample was selected using stratified random sampling technique giving due representation to different strata viz;

1. Gender
2. Subject specification
3. Board of education

**Tools**

The following tools were used for collecting relevant data for the study.

1. Mathematical Creativity Test
2. Spatial Ability Test

**Statistical Techniques Used For the Study**

The following statistical techniques is used

1. Preliminary analysis
2. Pearson’s product moment coefficient of correlation(r)
3. Test of significance of mean difference for large independent sample (t-test).

**Major Findings of the Study**

The findings of the study are the following

1. There is a significant positive and high relationship between Spatial Ability and Mathematical Creativity of higher secondary school students. (r = 0.756)
2. There exists a significant positive and very high relationship between Spatial Ability and Mathematical Creativity of Male higher secondary school students. (r = 0.832)
3. There exists a significant positive and high relationship between Spatial Ability and Mathematical Creativity of Female higher secondary school students. (r = 0.680)
4. There exists a significant positive and high relationship between Spatial Ability and Mathematical Creativity of Kerala state syllabus higher secondary school students. (r = 0.756)
5. There exists a significant positive and high relationship between Spatial Ability and Mathematical Creativity of CBSE syllabus higher secondary school students. (r = 0.760)
6. There exists a significant positive and high relationship between Spatial Ability and Mathematical Creativity of Science higher secondary school students. (r = 0.745)
7. There exists a significant positive and high relationship between Spatial Ability and Mathematical Creativity of Commerce higher secondary school students. (r = 0.768)
8. There is no significant difference in Spatial Ability between male and female higher secondary school students. (t value = 0.475)
9. There is no significant difference in Spatial Ability between state syllabus and CBSE syllabus higher secondary school students.

(t value = 1.85)

1. There is no significant difference in Spatial Ability between science and commerce higher secondary school students. ( t value = 0.128 )
2. There is no significant difference in Mathematical Creativity between male and female higher secondary school students. ( t value = 0.106 )
3. There is no significant difference in Mathematical Creativity between Kerala state syllabus and CBSE syllabus higher secondary school students.

(t value =0.543)

1. There is no significant difference in Mathematical Creativity between science and commerce higher secondary school students.(t value = 0.003)

**Tenability of the Hypothesis**

The tenability of the hypothesis is examined in the light of the above findings.

 Hypothesis (1) states that there is no significant relationship between Spatial Ability and Mathematical Creativity of higher secondary school students. The findings reveal that there is a significant positive and high relationship between Spatial Ability and Mathematical Creativity of higher secondary school students (r = 0.756). So hypothesis (1) is rejected.

 Hypothesis 2(a) states that there is no significant relationship between Spatial Ability and Mathematical Creativity of male and female higher secondary school students. The findings reveal that there is a significant positive and high relationship between Spatial Ability and Mathematical Creativity of male higher secondary school students (r = 0.832 ) and there is a significant positive and high relationship between Spatial Ability and Mathematical Creativity of female higher secondary school students (r = 0.680 ). So hypothesis 2(a) is rejected.

 Hypothesis 2(b) states that there is no significant relationship between Spatial Ability and Mathematical Creativity of Kerala state syllabus and CBSE syllabus higher secondary school students. The findings reveal that there is a significant positive and high relationship between Spatial Ability and Mathematical Creativity of higher secondary school students with Kerala state syllabus (r = 0.756 ) and CBSE syllabus (r = 0.760 ). So hypothesis 2 (b) is rejected.

 Hypothesis 2(c) states that there is no significant relationship between Spatial Ability and Mathematical Creativity of science and commerce higher secondary school students. The findings reveal that there is a significant positive and high relationship between Spatial Ability and Mathematical Creativity of higher secondary school science students (r = 0.745) and commerce (r = 0.768). So hypothesis 2(c) is rejected.

 Hypothesis 3(a) states that there is no significant difference between Spatial Ability of male and female higher secondary school students. The findings reveal that there is no significant difference between Spatial Ability of male and female higher secondary school students (t = 0.475). So hypothesis 3(a) is accepted.

 Hypothesis 3(b) states that there is no significant difference between Spatial Ability of higher secondary school students with Kerala state syllabus and CBSE syllabus. The findings reveal that there is no significant difference between Spatial Ability of higher secondary school students with Kerala state syllabus and CBSE syllabus. (t = 1.85). So hypothesis 3(b) is accepted.

 Hypothesis 3(c) states that there is no significant difference between Spatial Ability of science and commerce higher secondary school students. The findings reveal that there is no significant difference between Spatial Ability of science and commerce higher secondary school students (t = 0.128). So hypothesis 3(c) is accepted.

 Hypothesis 4(a) states that there is no significant difference between Mathematical Creativity of male and female higher secondary school students. The findings reveal that there is no significant difference between Mathematical Creativity of male and female higher secondary school students (t = 0.106). So hypothesis 4(a) is accepted.

 Hypothesis 4(b) states that there is no significant difference between Mathematical Creativity of higher secondary school students among Kerala State syllabus and CBSE syllabus. The findings reveal that there is no significant difference between Mathematical Creativity of higher secondary school students among Kerala state syllabus and CBSE syllabus (t = 0.543). So hypothesis 4(b) is accepted.

 Hypothesis 4(c) states that there is no significant difference between Mathematical Creativity of higher secondary school science and commerce students. The findings reveals that there is no significant difference between Mathematical Creativity of higher secondary school science and commerce students (t = 0.003). So hypothesis 4(c) is accepted.

**Conclusion**

Influence of Spatial Ability on Mathematical Creativity of Higher Secondary School Students was analyzed. Result shows that there is a significant positive and high relationship between the variables Spatial Ability and Mathematical Creativity. There is no significant difference in Spatial Ability between male and female students under Kerala state syllabus and CBSE syllabus, science and commerce students. Also there is no significant difference between Mathematical Creativity of male and female, students under state syllabus and CBSE syllabus, science and commerce students. The coefficient of correlation of the variables Spatial Ability and Mathematical Creativity for total sample and subsamples shows a positive correlation which indicates that Spatial Ability is one of the factors that affects positively the Mathematical Creativity of higher secondary school students.

**Educational Implications of the Study**

The value of any piece of research in education lies in the implications of the study. Based on the major findings of the present study, some practical suggestions have been given by the investigator to improve the present educational practices.

1. Resourceful activities suitable for developing creativity in students should be included in the mathematics curriculum.
2. Instead of using activities in textbooks, teachers should be able to design adequate external activities to pupils for developing creativity among them.
3. Teachers should observe each and every pupil’s way of problem solving, the way of responding to each question and the strategies adopted. This may differ from one to other. It helps to identify the mathematically creative pupil.
4. Conduct co curricular activities, science fares, exhibition and educational trips in schools by providing appropriate opportunities and atmosphere for creative expression.
5. Spatial ability can be improved through visual media. Visual programs should be performed and developed by expert team on incorporating topics like geometry, geography and science subjects.

**Suggestions for Further Research**

The findings of the study and limitations encountered in the present study helped the investigator to suggest the following for further research.

1. The study can be conducted at various levels such as secondary, graduate and post graduate level etc.
2. The present study can be extended to other states.
3. Role of teachers in promoting mathematical creativity can be studied.
4. Further studies can be conducted by extending other components of Mathematical Creativity and Spatial Ability.
5. A comparative study can be made on scores of Spatial Ability test of students having high achievement and low achievement in mathematics.
6. Studies can be done to identify the effect of mathematical creativity with other variables like resilience, attitude etc.
7. Construction and standardization of Spatial Ability Test and Mathematical Creativity Test can be made for secondary as well as higher secondary school students.

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**APPENDIX I**

**FAROOK TRAINING COLLEGE, CALICUT**

**MATHEMATICAL CREATIVITY TEST**

|  |
| --- |
| Mr.ANEES MOHAMMED. C VIJITHA. PAssistant Proffessor M.Ed StudentFarook Training College Farook Training Collegecalicut Calicut |

name: gender: male/female

class: subject: science/commerce

school: board: state/CBSE

 **DIRECTIONS**

This questionnaire is meant for finding your creativity in mathematics. It is different from your class examinations. The pattern of answering is shown at beginning of each question with examples. Answer the questions only after careful reading of the instructions and understanding the given examples. Examples given for each question need not be repeated. It will be good if the number and variety of answers are more. Answer the questions in the answer sheet provided along with the question paper.

**Write as many answers you can**

1. Write as many numbers as possible, so that the sum of digit is 7?

Example : write as many numbers as possible so that the sum of digits is 8?

Answer: 1) 80

 2) 71

 3) 152

2. Using the following bar diagram prepare as many questions and answers you can

Example : 1) who got highest mark?

Answer : Ravi

3. Draw figures of 4 squares arranged in different ways as possible

 Example

4. Write as many equations as possible using the symbol

 +, −, x, ÷, = and use the numbers 1, 3, 4, 5, 6 so as to get 18.

 Example : use 1, 3,4,7 so as to get 11.

 Answer : 1) 4+ 7= 11

 2) 3x4− 1=11

5. Write as many paths as possible from A to H through the edges of

D

A

E

F

C

H

B

G

 the cuboid ABCDEFGH

 Example: 1) ADH

 2) ABFGH

6. Using 15 matches 5 squares are made. Remove 2 matches and

 Prepare 4 squares as many ways as possible

 **Write the correct answer**

**7.** How many triangles are there in the following figure?

8. If (a+b)2 = a2 + 2ab + b2

(a+b+c) 2 = a2 +b2 +c2+2ab+2bc+2ac

 (a+b+c+d)2 = a2 +b2 +c2+d2+ 2ab+2ac+2ad+2bc+2bd+2cd

 Then write the expansion of (a+b+c+d+e)2

 **Choose the correct answer from your choices**

9. How many circles can be drawn with a single point as centre?

 a) one b) two c) infinite d) zero

10. Which of the following measure cannot be a chord of circle of

 radius 8 cm?

 a) 2cm b) 8cm c) 16 cm d) 20 cm

11. Among some scores the smallest is 36 and the largest is 56

 which of the following cannot be a mean of scores

 a) 39.4 b) 43$\frac{1}{2}$ c) 49 d) 60

 **Imagine and complete the figures**

12. Complete the figure using geometrical figures

13. Form mathematical shapes by joining adjacent points

**APPENDIX II**

**FAROOK TRAINING COLLEGE, CALICUT**

**SPATIAL ABILITY TEST**

|  |
| --- |
| Mr.ANEES MOHAMMED. C VIJITHA. PAssistant Proffessor M.Ed StudentFarook Training College Farook Training CollegeCalicut Calicut |

**DIRECTIONS**

This booklet contains 30 questions. You must answer each question. You are provided with 4 choices for answers viz, A, B, C, D. Read the directions carefully and put ‘$√$’ in the appropriate box of right answer. Only **one** correct answer for each question. If you have difficulties with one problem don’t spend too much of time on it. Omit it and go on to the next problem. After the examination, return the answer sheet.

 **Which one of the following figures A, B, C, D will be the right choice if we arrange the first figure in a proper manner?**

 A B C D

 **1.**

**2.**

**3.**

**4.**

**5.**

**6.**

**7.**

**8.**

**9.**

**10.**

**Count the number of BLOCKS in each shape?**

**20**

**14**

**12**

**10**

**11**. A B C D

**18**

**15**

**12**. A B C D

**12**

**16**

**13**. A B C D

**7**

**6**

**5**

**9**

**16**

**12**

**14**. A B C D

**10**0

**9**

**15**. A B C D

**9**

**7**

**8**

**6**

**12**

**10**

**8**

**6**

**16**. A B C D

**Which one is identical to the first if we rotate the first figure?**

 A B C D

**17.**

**18.**

**19.**

**20.**

**21.**

**22.**

**Locate the Figure: (question 23 and 24 are based on the given figure)** 

**23.** Imagine you are standing near the flower and facing the tree. Now point out the cat .The position of cat will be

cat

Flower

Tree

cat

Flower

Tree

cat

Flower

Tree

Cat

Flower

Tree

**A B C D**

**24.** Imagine you are standing near the car and facing the traffic light. Now point out the stop sign .The position of the stop sign will be

**A B C D**

StopSign

StopSign

Light

Light

Car

Light

StopSign

Car

Light

Car

Car

StopSign

**Which one of the four ANSWER FIGURES should come after the PROBLEM FIGURES, if the sequence were continued?**

**25.**

**ANSWER FIGURES**

**PROBLEM FIGURES**

**A**

**D**

**C**

**B**

**ANSWER FIGURES**

**PROBLEM FIGURES**

**A**

**D**

**C**

**B**

**26.**

**Which cube CANNOT be based on the unfolded cube?**

**A B C D D**

**A B C D D**

**27.**

**28.**

**Which one is identical to the first?**

**29.**

A

B

C

D

**30.**

A B C D

 **APPENDIX III**

**SPATIAL ABILITY TEST ANSWER SHEET**

Name: Gender: male/female

class: subject: science/commerce

school: board: state/CBSE

 **A B C D** **A B C D**

1. 16.

 2. 17.

 3. 18.

 4. 19.

 5. 20.

 6. 21.

 7. 22.

 8. 23.

 9. 24.

 10. 25.

 11. 26.

 12. 27.

 13. 28.

 14. 29.

 15. 30.