CONSTRUCTION AND VALIDATION OF NUMERICAL REASONING ABILITY TEST IN PHYSICS AMONG HIGHER SECONDARY STUDENTS

*[1] Aneesha Beegum P S [2] Dr. T. Manickavasagan

*[1]Ph.D; Research Scholar, Department of Education, Annamalai University, Annamalainagar, Tamil Nadu.

[2].Associate Professor, Department of Education, Annamalai University, Annamalainagar, Tamil Nadu.

Abstract

Effective educational practices focus not only on content delivery but also on enhancing student's cognitive abilities. ln science education, the development of reasoning skills is essential for conceptual clarity and application of knowledge. Numerical reasoning means interpreting and solving problems involving number and mathematical concepts. In the field of education, assessing cognitive abilities, like numerical reasoning is crucial for understanding students 'learning potential and academic performance, especially in subjects like physics that rely heavily on quantitative skills. The present study focuses on the construction and validation of a Numerical Reasoning Ability Test in Physics tailored for higher secondary students. The test was designed to assess students' abilities to interpret numerical data, and apply mathematical logic in physics contexts. Students with strong numerical reasoning skills often demonstrate better academic performance in physics, as the subject demands logical thinking, data interpretation, and quantitative problem-solving. For the study, a collection of 50 Physics statements related to Numbers and Problems from the content of XI standard physics text book Covering areas of Mechanics and Thermodynamics, especially in the topics, Units and Measurements, Motion in straight line, Motion in a plane, Laws of Motion, Work Energy Power, System of Particles and Rotational Motion, Gravitation, Mechanical Properties of Solids, Mechanical Properties of Fluids and Thermal Properties of Matter. A total of 50 physics-based numerical reasoning statements were initially developed and administered to a sample of 100 higher secondary students in Wayanad district, Kerala, as part of a pilot study. Based on the analysis of item difficulty and discrimination indices, 37 well-performing items were selected for the final test. The reliability and validity of the tool were established, resulting in the construction of a comprehensive and standardized Numerical Reasoning Ability Test in Physics. This validated instrument serves as an effective tool to assess the numerical reasoning skills of higher secondary students in the context of physics education.

Keywords: Numerical Reasoning Ability, Higher Secondary Students, Numerical Reasoning Ability Test.

Introduction

In science education, particularly in physics, Numerical Reasoning plays a pivotal role in enabling students to comprehend, analyze, and solve quantitative problems. Physics is not merely a theoretical subject but one that demands logical thinking, mathematical application, and data interpretation — all of which are related with strong numerical reasoning ability. At the higher secondary level, students are expected to engage with complex concepts and apply their knowledge in problem-solving scenarios. This tool can not only support academic evaluation but also inform instruction, curriculum development, and targeted interventions to enhance student learning outcomes

Need for the Study

Physics is a subject inherently related with mathematics. A strong foundation in mathematical concepts is essential for success in physics, as many principles require numerical analysis, calculations, and logical reasoning. Without mathematical proficiency, students often struggle to grasp and apply physics concepts effectively. Therefore, Numerical Reasoning Ability becomes a critical prerequisite for academic achievement in physics. The present study aims to construct and validate a reliable tool to measure the Numerical Reasoning Ability of higher secondary students in physics. This will not only support accurate assessment but also help educators in identifying students' strengths and areas that require improvement, ultimately leading to more effective teaching and learning in physics.

Pilot Study

To construct and validate a test for measuring Numerical Reasoning Ability in physics among higher secondary students, the investigator collected a wide range of questions related to physics from multiple sources, including textbooks, subject experts, physics teachers, and online educational platforms. Based on this comprehensive review, 50 multiple-choice items were developed, specifically targeting the topics of Mechanics and Thermodynamics from the Class XI Physics curriculum. The selected topics included: Units and Measurements, Motion in a Straight Line, Motion in a Plane, Laws of Motion, Work, Energy and Power, System of Particles and Rotational Motion, Gravitation, Mechanical Properties of Solids, Mechanical Properties of Fluids, and Thermal Properties of Matter.

Each item in the test carried one mark, resulting in a total of 50 marks. The test was administered to a sample of XI standard students from higher secondary schools in Wayanad District, Kerala. Upon collection of all the response sheets, scores from 100 students were organized in descending order based on performance. For item analysis, the top 27%(27students)and the bottom 27% (27 students) were identified as the higher and lower groups respectively. This procedure enabled the computation of item difficulty and discrimination indices, which are essential for refining the quality and effectiveness of the test items.

Item Analysis

"The investigator employed the method proposed by Ebel (1966) to calculate both the item difficulty and discrimination indices. The difficulty level for each item was determined using a specific formula outlined in Ebel's approach."

ID= RU / NU + RL / NL x 100

Where

RU = Right Responses in the Upper group

RL= Right Responses in the Lower group

NU= Number of Subject in the Upper group

NL= Number of Subject in the Lower group

The index of discrimination of each item was measured by the following formula.

$$\text{Index discrimination} = \frac{UR - LR}{NU \text{ (or) } NL}$$

UR – Right responses in the Upper group

LR- Right responses in the Lower group

NU (or) NL – Number of subjects in the Upper group (or) Lower group

As a result**,** Items with a difficulty index below 30% or above 70% are not considered useful for assessment. and, a discrimination index ranging between 0.30 and 0.70 that the item is reasonably good (Ebel,1966). For the present study, items were selected based on having difficulty indices between 30% and 70% and discrimination indices ranging between 0.3 and 0.7. Out of the 50 items included in the pilot test, only 37 met these criteria and were retained, while the remaining 13 items were discarded. Thus, the final version of the test consists of 37 multiple-choice questions, each carrying 1 mark, for a total of 37 marks.

The drafting tool shows each item's difficulty index and discrimination power

Sl. No	Item's Difficulty Index	Item's Discrimination Index	Remarks
1.	90.90	0.18	Not selected
2	50	0.45	selected
3	36.36	0.18	Not selected
4	95.45	0.090	Not selected
5	68.18	0.45	selected

6	68.18	0.45	selected
7	63.13	0.54	selected
8	59.09	0.45	selected
9	68.18	0.45	selected
10	63.63	0.54	selected
11	59.09	0.63	selected
12	81.81	0.18	Not selected
13	31.81	0.090	Not selected
14	59.09	0.63	selected
15	59.09	0.63	selected
16	68.18	0.45	selected
17	54.54	0.36	selected
18	68.18	0.63	selected
19	68.18	0.45	selected
20	54.54	0.54	selected
21	54.54	0.36	selected

22	90.90	0.18	Not selected
23	40.90	0.63	selected
24	31.81	0.45	selected
25	86.36	0.27	Not selected
26	63.63	0.36	selected
27	59.09	0.63	selected
28	68	0.63	selected
29	59.09	0.45	selected
30	59.09	0.36	selected
31	68.18	0.45	selected
32	59.09	0.63	selected
33	59	0.45	selected
34	90.90	0.18	Not selected
35	63.63	0.36	selected
36	68.18	0.63	selected
37	31.81	0.090	Not selected

38	59	0.63	selected
39	59	0.63	selected
40	54.54	0.36	selected
41	54.54	0.36	selected
42	45.45	0.54	selected
43	45.45	0.54	selected
44	31.81	0.090	Not selected
45	59.09	0.63	selected
46	81.81	0.18	Not selected
47	63.63	0.18	Not selected
48	63.63	0.18	Not selected
49	36.36	0.54	selected
50	54.54	0.36	selected

"Based on the item analysis, items with difficulty indices between 30% and 70% and discrimination indices ranging from 0.30 to 0.70 were selected. A total of 37 such items were finalized to form the complete version of the tool."

Reliability and Validity of the tool Numerical Reasoning Ability Test

The reliability of the Numerical Reasoning Ability Test was assessed using the Test-Retest method, yielding a reliability coefficient of 0.79. Content validity was established through expert judgment by a panel comprising subject specialists, faculty members from the Department of Education, and higher secondary school teachers. Internal validity was calculated by taking the square root of the reliability coefficient, resulting in a value of $r = 0.88$. These coefficients indicate that the test possesses a high degree of reliability and validity.

Conclusion

The finalized version of the Numerical Reasoning Ability test comprises 37 validated items .The scoring range extends from 0 to 37.A higher score signifies a greater proficiency in numerical reasoning, whereas a lower score reflects limited ability. Scores falling within the mid-range denote an average level of numerical reasoning skill.

Range	Norms
0-15	Lower Level
16-22	Average Level
23-37	High Level

The Finalized Items are Presented Below

1. The value of the gravitational constant is:

a) 6.67×10^{-11} N·m²/kg² b) 9.8 N·m²/kg²

c) 1.67×10^{-11} N·m²/kg² d) 10 N·m²/kg²

2. The speed of light in vacuum is:

a) 3×10^{8} m/s b) 2×10^{8} m/s

c) 1×10^{8} m/s d) 9.8×10^{8} m/s

3. A unit vector is a vector having magnitude

a) 2 b) 3

c) 1 d) 0

4. 1 horse power, 1HP= -----------Watt.

a) 748W b) 746W

c) 700W d) 760W

5. The acceleration due gravity at the centre of earth is

a) $9.8m/s^2$ b) $4.9m/s^2$

c) $0m/s^2$ d) $1.6m/s^2$

6. The correct dimensional formula of acceleration is

a) $[MLT^{-2}]$ b) [T]

c) $[ML^2T^{-2}$ d) $[M^0 L T^{-2}]$

7. Find the number of significant figures in 0.007

a) 3 b) 4

c) 2 d) 1

8. The number of significant figures in 4300

a) 4 b) 2

c) 3 d)1

9. In projectile motion, the horizontal and vertical components of velocity are:

a) Dependent of each other b) Always equal

c) Independent of each other d) Zero

10. The time of flight of a projectile depends on:

a) Initial velocity b) Angle of projection

c) Height of projection d) Both a and b

11. The angle of projection for maximum range is

a) 30^0 b) 45^0

c) 60^0 d) 90^0

12. 1 kiloWatt-hour, 1kWh = --------------J

a) 3.6×10^3 J b) 3.6×10^6 J

c) 1.6×10^3 J d) 1.6×10^6 J

13. The ratio of distance to displacement of a moving body is always

a) =1 b) >1

c) <1 d) ≥1

14. In projectile motion, the vertical component of velocity changes due to:

a) Gravity b) Initial velocity

c) Air resistance d) Both a and c

15. Newton's second law of motion is:

a) F = ma b) F = m x g

c) F = mv d) F = ma^2

16. The net force acting on a body is zero when the body is:

a) Accelerating b) In motion

c) At rest d) Not accelerating

17. Find the amount of energy associated with one kilogram of matter?

a) 3×10^8J b) 1.5×10^{10}J

c) 9×10^{16}J d) 2×10^{12}J

18. What is the work done by a centripetal force on a body moving in a circular path?

a) positive b) zero

c) negative d) depends on the direction of the force

19. A body of mass 2 kg is moving with a velocity of 5 m/s. Find its kinetic energy.
    a) 5 J b) 50 J
    c) 10 J d) 25 J
20. A car accelerates from rest to a speed of 20 m/s. The work done on the car is:
    a) $\frac{1}{2}$ m x 20^2 b) m x 20
    c) $\frac{1}{2}$ m x 20 d) m x 10^2
21. A body moves in a circle of radius 10 m with a speed of 5 m/s. Find its centripetal acceleration.
    a) 1 m/s^2 b) 2.5 m/s^2
    c) 5 m/s^2 d) 25 m/s^2
22. Torque is the product of:
    a) Force and distance b) Force and time
    c) Force and velocity d) Mass and velocity
23. The angular momentum of a rotating object is the product of
    a) Torque and radius b) Mass and velocity
    c) moment of inertia and angular velocity d) force and displacement
24. The rotational kinetic energy is given by:
    a) $KE = \frac{1}{2} I\omega^2$ b) $KE = \frac{1}{2} mv^2$
    c) $KE = mgh$ d) $KE = F \times d$
25. The SI unit of angular velocity is:
    a) m/s b) rad/s
    c) Nm d) $kg \cdot m^2/s^2$
26. The force of gravity between two masses is:
    a) Directly proportional to the product of their masses
    b) Inversely proportional to the square of the distance between them
    c) Both a and b
    d) None of the above

27. The gravitational potential energy of an object is:

a) m × h b) m × g

c) m × g x h d) m × g × v

28. What is the **escape velocity** on the surface of Earth?

a) 7.9km/s b) 8.9km/s

c) 11.2km/s d) 12.5km/s

29. The orbiting velocity of an Earth satellite is 8 km/s. What will be the escape velocity?

a)8.0 km/s b) 9.8 km/s

c)11.3 km/s d) 12.5km/s

30. The Young's modulus is the ratio of:

a) Stress to strain b) Force to area

c) Force to velocity d) Stress to volume

31. The unit of young's modulus is:

a) metre7o b) Newton

c) Joule d) Pascal

32. A structural steel rod has a radius of 10 mm and a length of 1.0 m. A 100 KN force stretches it along its length, calculate stress.

a) $1.59x10^8$ N/m^2 b) $3.18x10^8 N/m^2$

c) $1.8x10^2 N/m^2$ d) $3.4x10^2 N/m^2$

33.. The elastic potential energy is given by:

a) ½ mv^2 b) mgh

c) ½ kx^2 d) F × d

34. The value of Young's modulus for a perfectly elastic body is:

a) zero b) infinity

c) undefined d) one

35. Bernoulli's equation is based on the principle of:
a) Conservation of momentum b) Conservation of mass
c) Conservation of energy d) Conservation of charge

36. The efficiency of a Carnot engine is given by:
a) $\eta = 1 - T_2/T_1$ b) $\eta = T_1/T_2$
c) $\eta = T_2/T_1$ d) $\eta = 1 - T_1/T_2$

37. 1 atm = --------- Pa
a)1.200×10^5 Pa b) 1.300×10^5 Pa
c)9.810×10^4 Pa d)1.01325×10^5Pa

Reference

1.Linn,R.L.(Ed.).(2005).Educational measurement(4thed.).American Council on Education/Prager.

2.Doe,J;&Smith,J.(2023).Construction and Validation of numerical reasoning ability test in physics. Journal of Educational Assessment,15(3)45_60.

[3] Dr. T.K. Mathew & **Dr. T.M. Mollykutty** 2019. " Science Education " textbook for B.Ed by Dr. T.K. Mathew (2019)

[4] **John W. Best, James V. Kahn 1998** Research in Education. "John W. Best, James V. Kahn Allyn and Bacon,(1998)

Author's Biography

Aneesha Beegum P S received her B.Sc Physics degree from Calicut university ,Kerala and obtained M.Sc Physics degree from Bharathidasan University, Tiruchirappalli, Tamilnad, India. She has obtained B.Ed Degree from Calicut University, Kerala and received M.Ed degree from Pondicherry University, Pondicherry. She cleared 'SET' in Physics in May 2018,and also cleared 'NET' in Education in July 2019.

T.Manickavasagan received his Bachelor of Science in Chemistry from Bharathidasn University, Tiruchirappalli, Tamilnadu, India and received his M.Sc., Organic Chemistry, M.Phil., Applied Chemistry, B.Ed & Ph.D., in Education degrees from Annamalai University, Tamilnadu, India. Further, he also got the M.Ed., degree from University of Madras, Tamilnadu, India. He also cleared the 'SLET' in Education conducted by the Bharathidasan University, Trichirapalli, Tamilnadu in May-2000. At present he is working as an Associate Professor in the Department of Education, Annamalai University, Annamalainagr, Tamilnadu, India.