**International Journal of Research in Medical and Basic Sciences**
Volume 9 Issue 11, November 2023 ISSN: 2455-2569 Impact Factor: 7.028
Journal Homepage: http://mbsresearch.com, Email: mbsresearchp@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal

# UNDERSTANDING LIGHT AND OPTICS EXPLORING THE BEHAVIOUR AND APPLICATIONS OF LIGHT

**JAGVIR SINGH**

Department of Physics, Om Sterling Global University, Hisar, India

**DOI:ijmra.mbs.33987.66489**

## Abstract

*The scientific community may simultaneously accept multiple models for any given scientific issue, as evidenced by the history of science. The wave and corpuscular theories of light are one example of this. This project aims to provide upper secondary pupils with a model of light education. The subject is too hard to teach, even though it appears to be at the core of contemporary physics. This led us to develop and implement a didactical strategy, the assessment of which appears advantageous for teaching this subject. Contrasted with standard guidance, our own works on's how understudies might interpret the idea of light.The didactical method, a concept for a scientific transformation of educational models with regard to light, was implemented with fifty (50) Upper Secondary Education students in Delhi's Experimental Group during the 2016–2017 academic year. As the control group, we have eighty (80) other kids being taught in the traditional manner. The primary research is presented in this paper. In this computer-supported endeavour, we discuss the laboratory experiments and the instructional methodology. References are additionally made to the discoveries and expansive inductions drawn from the factual investigation of the pre, post, and last testing.*

***Keywords:*** *Behaviour Light, Lights, Optics, Applications.*

## 1. INTRODUCTION

In secondary education, the geometrical or diagrammatic model is frequently employed to acquaint students with light phenomena and their interpretations. This model makes use of lines to depict the light's rays, arrows to show the light's direction of motion, and a series of mathematical formulas (such as the law of Snell) to compute the interactions between the light and objects along its propagation route. A beam of light is made up of a collection of rays. This model claims to be agnostic on the nature of light, meaning it doesn't endorse a particular theory about whether light is body-like or wavelike.

Numerous obstacles prevent the geometrical model of optics education from being widely used. Even students who have taken the necessary courses typically struggle to describe even the most basic aspects of light propagation when they try to draw the correct light rays and connect them to the light's source and the objects that they interact with. Moreover, it appears that the geometrical model's dependence impedes later Science & Education (2005) attempts to instruct students in phenomena that need considering light as a wave, such as interference and diffraction. The number line in arithmetic instruction is one prominent example of how traditional models used in education are frequently thoroughly revised, so even though there aren't many voices challenging the value of the geometrical model of light in physics education, one might anticipate that the geometrical model is about to come under similar scrutiny.The review's targets are to: a) determine the convictions, understanding, and skill of upper optional school understudies who were shown light utilizing the customary, exemplary technique; b) recommend another didactical methodology that applies science to the change of instructive models with respect to light for upper auxiliary school understudies; and c) present the discoveries and wide ends from the factual examination of post-and last test information. The explanation this subject was chosen is that references to current logical speculations are remembered for Greece's upper auxiliary physical science educational plan.

Our didactical approach's main points are:

(i) To accentuate the double idea of light (wave-molecule duality) and show models of light through trial and error,

(ii) To make, or build, electronic informative materials that permit understudies to pick the best model of light to portray a peculiarity. These materials will contain research facility exercises, reproductions, and perceptions.

(iii) To compose: as a means of imparting knowledge of these models, develop course modules for the model of light that have a particular structure.

According to the review of the pre-research answers regarding light, most students have a poor understanding of this subject when taught in the traditional manner. Despite appearing to represent the foundation of contemporary physics, it is extremely complex to teach. This information led us to develop and implement a didactic method, the assessment of which indicates that it will help with the teaching of this subject.

## 2. LITERATURE REVIEW

Balabanoff, M. E., Al Fulaiti, H., Bhusal, S., Harrold, A., & Moon, A. C. (2020), Three different levels of knowledge were identified in the model of students' understanding that was produced by a knowledge analysis of the interview data. In view of the qualities of the understudies' mental designs and ways to deal with wave-molecule duality, these levels were separated from each other.The lowest level of thinking created piecemeal explanations, depended heavily on intuition, and limited the description of light's action to that of a wave or particle.

Dholakia, K., &Zemánek, P. (2010), The most recent experimental research in the area is examined, and theoretical theories are starting to come together to explain the observed binding behaviour. Prospective themes and problems are examined together with recent connections between optical binding and nonlinearity.

Greentree, A. D., Tahan, C., Cole, J. H., &Hollenberg, L. C. (2006) presented a mesoscopic-scale optical system with tightly coupled dynamics. We create long-lived, highly interacting clothed states, or polaritons, by bringing photons into a two-layered cluster of associated optical depressions, each holding a solitary two-level iota in the photon-barricade space. According to our findings, the system will experience a typical quantum phase transition at zero temperature, going from a Mott insulator (with excitations localised on each site) to a superfluid (with excitations delocalized throughout the lattice). Furthermore, this system's capacity to link light to and from specific cavities may prove helpful in the development of other quantum-mechanical systems, such as tuneable quantum simulators.Lenton, I.C., Armstrong, D.J., Stilgoe, A.B., Nieminen, T.A. and Rubinsztein-Dunlop, (2020), the ways in which motile and non-motile particles are oriented differently, and investigate annular beams and the situations in which they can be useful in the management of non-spherical particles or cells. We plot the path taken by the E. coli using simulations. An understanding of the stability of an intermediate rotation with regard to the intended orientation can be gained by estimating the trap stiffness along the trajectory. Lerner, A., &Shashar, N. (2014), studied polarised "light pollution" caused by human-caused causes, including reflection from glass panes, automobile bodywork, asphalt surfaces, and other man-made objects, which are now recognised to create ecological traps for polarotactic insects.Molloy, J. E., & Padgett, M. J. (2002), aim to cover the primary uses of optical tweezers, provide some recent technological advancements, explain the underlying process, and make predictions about future uses in both biological and non-biological domains.

## 3. THE BEHAVIOR OF LIGHT

The law of reflection also pertains to the ray. This is implied by the fact that although mirrors are transparent to ether particles, they have the ability to reflect light waves. It's crucial to keep in mind that the ray is merely a mathematical tool that we employ to describe a wave front rather than an actual object. Instead, reality is found in the wave front.Huygen's theory also holds true in Michelson interferometers or cavities where light is trapped between two parallel mirrors. The fastest path is taken by light, not the shortest, therefore rays, not beams, are important. This indicates that in cavities and in a Michelson interferometer, the wave fronts are always parallel to the mirrors. An alternative interpretation of this would be to consider that light behaviour is defined by the combination of the ether's state of motion and the mirrors' orientation. Light behaviour is unaffected by the equipment's translational motion.because the boundary conditions governing the wave fronts remain unchanged by such migration. Therefore, as Potier (1882) said, translational motion of the apparatus cannot cause light behaviour to alter in a way that takes longer. Potier's theory runs counter to both the ether hypothesis and Huygen's principle. For five years, Michelson rejected this notion.

The 'creation' of the ridiculous concept of dilation of time served as a cover-up for the irregular introduction of an ether wind effect in the transverse arm of Michelson's test. In addition to creating the twin paradox, this error contributed to some uncertainty about the structure of light. This proves that humans are far more adept at creating lies than they are at learning the truth. Thus, it is evident that our inadequate comprehension of light's behaviour is the root cause of the paradoxes in contemporary physics. We haven't noticed that two models are required for light, specifically even though there is only a 1 μradian difference.

- beam with relevant transverse ether wind and
- ray with transverse ether wind as not relevant,

## 4. APPLICATIONS OF OPTICS

The field of optical research has several uses. Numerous areas of physics make use of optics' features. Among the uses for optics are:

- When using convex and concave lenses, the refraction phenomena is used to create a picture of the object.

- In the field of geometrical optics, light is represented by rays. It is applied to research on the formation of images in optical systems.
- It is employed in optical diagnostics for medical purposes to identify flaws and mysteries in the human body.
- Therapeutic procedures on human tissues also employ optics.
- The use of contact lenses and spectacles to treat some vision impairments.
- For the use of telescopes to examine distant universes.
- The use of microscopes to discover microorganisms.
- Optical fibres, mirrors, lasers, and lenses are employed in surgery, weapons targeting, and data transmission, storage, and retrieval.

## 5. RESEARCH METHODOLOGY

There are seven units in the developed didactical approach:

1. Propagation of light
2. Reflection of light
3. Interference – Diffraction of light
4. Refraction of light
5. Absorption of light
6. Analysis – Synthesis of light
7. Polarization of light

During the 2016–2017 academic year, Delhi, India, upper secondary pupils (17 years old) received the intervention. Fifty (50) students in total, split into two classes of twenty-five (25) and twenty-five (25) students, participated in this study. Eight (6) teams of three (8) students and two (2) common students were formed from each group (there was one team of two students). They took post-tests and final exams in order to evaluate the proposal. The experimental group consists of these fifty pupils. We have fifty (80) additional students in the control group, split into two classes of twenty-five (40) each.

## 5.1.Research Description

The software (simulations, visualisations, theoretical presentation) and laboratory experiments (conventional methods) combine to form the application. The platform consists of a collection of HTML files that follow the previously specified five levels of the instructional paradigm. We explicitly made the included reproductions and representations utilizing 3D Studio Max, Visual Fundamental 6.0, and OpenGL for this application-study.The curriculum has been broken down into seven topic blocks, or units. Every unit is separated into three segments: the fundamental subject (like impression of light) and the wave and molecule models of light. In each unit, the two parts — the molecule and wave models of light — continue as before. This is to allow for the potential for autonomous instruction of every topic unit. The core content that students need to acquire is presented in an organised manner by these subject units, which serve as the foundational unit of learning. From our perspective, when the student adheres to the rational, suggested sequence, this promotes a progressive study of the material. Any program with these sorts of qualities needs to consider the educational point, which for our situation is about the idea of light (light models). Every thought being educated or model gave, including texts, pictures, designs, activitys, recordings, and portrayals, has its own set of carefully chosen media and forms.

## 6. RESULTS

The accompanying tables show a few trademark results for a few inquiries. We used SPSS10 (t-test) for the factual examination of the understudies' reactions, noticing that ten (10) is the best conceivable score — magnificent — for all tests.

**Table 1**: Post-Test Average Points Per Unit for the Experimental Group (Eg) and Control Group (Cg)

| S.NO. | Unit | Post-trial of Control Gathering (CG) | Post-trial of Exploratory Gathering (EG) |
|---|---|---|---|
| 1 | Propagation of light | 5.74 | 9.25 |
| 2 | Reflection of light | 6.20 | 9.30 |
| 3 | Interfrence-Diffraction of light | 4.74 | 8.90 |
| 4 | Refraction of ligh | 5.29 | 9.04 |
| 5 | Absorption of light | 4.60 | 8.32 |
| 6 | Analysis – Synthesis of light | 4.81 | 8.75 |
| 7 | Polarization of light | 4.11 | 8.43 |

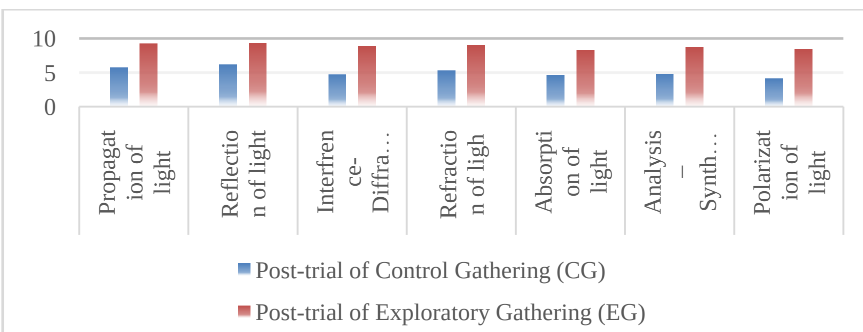


**Figure 1:** Post-Test Normal Focuses Per Unit for the Trial Gathering (EG) and Control Gathering (CG)

**Table 2**The typical score for the exploratory gathering on the last test and the post-test all out (Eg)

| Unit | Post-test total (CG) | Post-test total (EG) | Final-test (EG) |
|---|---|---|---|
| 1 | 5.75 | 8.89 | 8.70 |

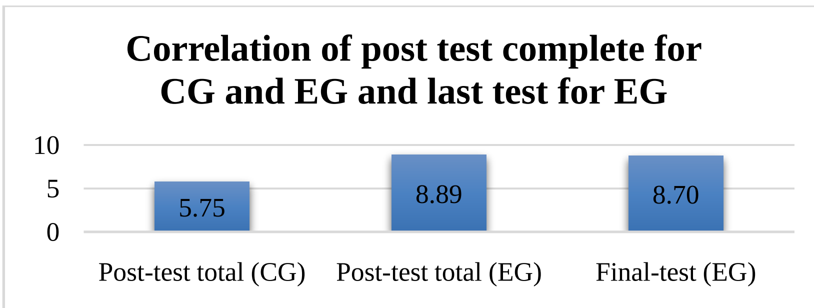


**Figure 2:**Mean Score for Control Group (CG), Experimental Group (EG), and Final Test for Experimental Group (EG) Post-Test Total

### 6.1.PER UNIT RESULTS

The greatest score—excellent—for each exam is 10, according to the statistics we offer based on the responses to the post-test questions for each unit. Accordingly, this score should be contrasted with the mean post-test score for every one of the seven units. The 10th and last inquiry on each test pose to you to choose the most ideal model of light to portray and make sense of the peculiarity you shrouded in this part.QuestionWhich light model—a) the two particles and waves, b) just the molecule model, c) just the wave model, or d) neither particles nor waves —is the best fit to explain and characterise this phenomena of light? Following the informative mediation, understudies gave precise reactions on the translation of peculiarities utilizing the most reasonable model, with rates going from 90% to almost 100%.The learning mediation had very fantastic outcomes, with a typical improvement in understudy answers of 3 to 4 degrees (on a size of 10) across virtually all inquiries. The remarks and perceptions on the information gathered in each subject are ordered here.

## I. Propagation of light

The experimental group (EG) scored 9.25 (standard deviation 0.77) and the control group (CG) scored 5.75 (standard deviation 1.25) on the post-test.

**Table 3:** Propagation of Light: Percentage of Accurate Responses for Each Question in the Post-Test for the Trial Gathering (Eg) and Control Gathering (Cg).

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CG | 60.2 | 56.3 | 70.2 | 55.0 | 58.2 | 53.0 | 55.0 | 61.2 | 50.2 | 58.2 |
| EG | 93.4 | 97.7 | 100.1 | 87.4 | 93.7 | 89.2 | 87.3 | 95.9 | 82.0 | 95.9 |

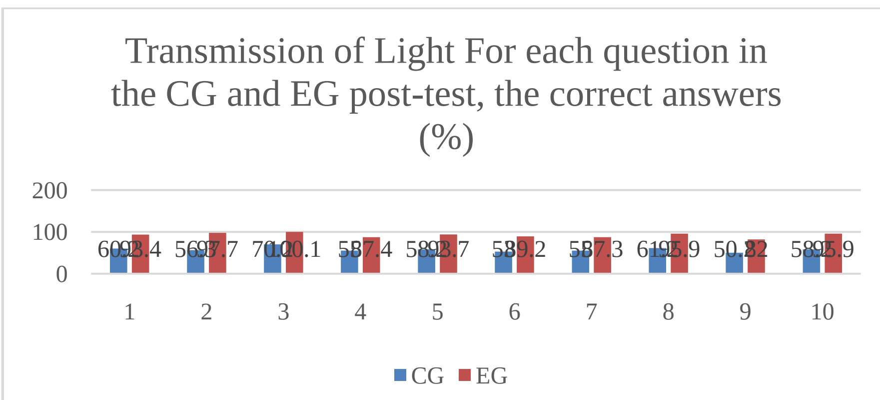


**Figure 3:**Light propagation: percentage(%) of right responses for each item on the post-test for the Exploratory Gathering (EG) and Control Gathering (CG).

"Shadow is an aftereffect of the accompanying: a) impression of light, b) refraction of light, c) rectilinear spread of light, d) ingestion of light from the bodies," peruses the fifth inquiry, for example.

## II. Reflection of light

The Experimental Group (EG) scored 9.30 (standard deviation 0.81) while the Control Group (CG) scored 6.20 (standard deviation 1.45) on the post-test.

**Table 4:**Light Reflection: The Proportion of Accurate Responses for Each Question in the Post-Test for the Benchmark Group (Cg) and the Trial Gathering (Eg)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CG | 64.2 | 82.2 | 75.0 | 29.0 | 61.0 | 60.2 | 70.2 | 78.2 | 26.2 | 71.0 |
| EG | 91.7 | 95.5 | 95.5 | 89.7 | 95.4 | 93.4 | 93.8 | 98.0 | 85.3 | 93.5 |

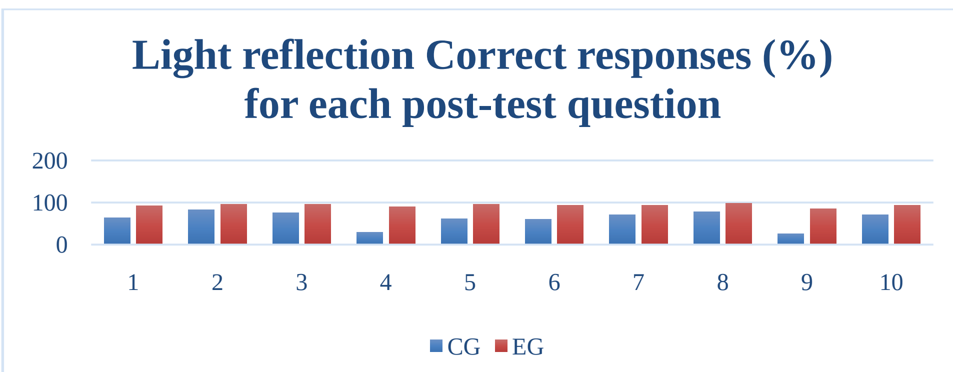


**Figure 4:**Percentage (%) Of Right Answers for Each Question in the Post-Test for the Benchmark Group (CG) and Trial Gathering (EG): Light Engendering

For example, the fourth inquiry pose: "The peculiarity of reflection is normal in a wide range of waves, electromagnetic and mechanical; a) limited to electromagnetic waves recognized by the natural eye; b) doesn't make a difference to infrared and bright radiation; c) restricted to radio waves."

### III. Interference – Diffraction of light

The pre-test mean score was 4.70 (standard deviation 1.83) while the post-test mean score was 8.90 (standard deviation 1.00).

**Table 5**: Level of Right Responses for Each Inquiry in the Post-Test for the Benchmark Group (Cg) and Exploratory Gathering (Eg): Obstruction - Diffraction of Light

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CG | 74.2 | 72.2 | 47.0 | 52.3 | 32.2 | 36.3 | 40.2 | 34.3 | 31.0 | 51.0 |
| EG | 98.0 | 97.7 | 83.1 | 87.3 | 63.3 | 89.7 | 89.7 | 93.5 | 85.3 | 80.0 |

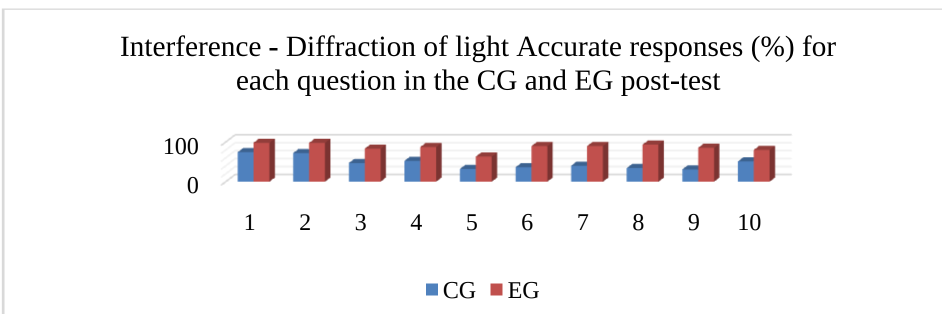


**Figure 5:**Rate (%) Of Right Solutions For Each Inquiry In The Post-Test For The Benchmark Group (CG) And The Trial Gathering (EG) Obstruction - Diffraction of Light

"For the most part, diffraction happens when light experiences an obstruction or cut having aspects comparative with the frequency of the proliferating wave": a) a lot more modest, b) a lot bigger, c) a similar significant degree, d) either a lot more modest or a lot bigger," peruses the fifth inquiry, for example.

## IV. Refraction of light

Mean scores were 5.28 (standard deviation 2.13), for the pre-test, and 9.04 (standard deviation 1.01), for the post-test.

**Table 6:** Refraction of Light: The Portion Of Right Solutions For Each Inquiry In The Post-Test For The Trial Gathering (Eg) And Control Gathering (Cg)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CG | 64.2 | 76.1 | 56.2 | 40.2 | 38.3 | 64.2 | 62.2 | 40.3 | 42.2 | 44.1 |
| EG | 98.1 | 99.9 | 89.3 | 76.4 | 78.9 | 91.7 | 95.9 | 93.7 | 89.6 | 93.7 |

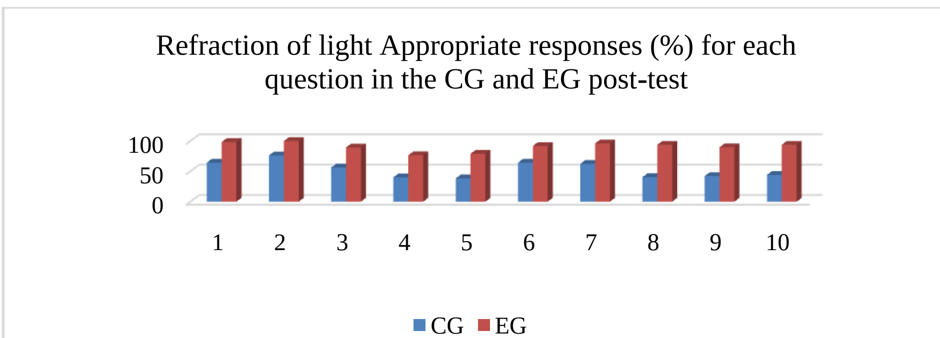


**Figure 6:**Refraction of light: The rate (%) of right reactions for each inquiry in the post-test for the Exploratory Gathering (EG) and Control Gathering (CG)

The eighth inquiry, for example, inquires: "The point of refraction, as contrasted and the point of rate, is: a) less, b) the equivalent, c) more prominent, d) might be any of the above when one monochromatic light bar passes from one straightforward medium into one more with an alternate file of refraction."

## V. Absorption of light

The average score was 4.56 (standard deviation 1.80) for the pre-test and 8.35 (standard deviation 1.02) for the post-test.

**Table 7**: Light Assimilation: The Extent of Right Reactions for Each Inquiry in the Post-Test for the Benchmark Group (Cg) and the Trial Gathering (Eg)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CG | 46.1 | 76.3 | 47.8 | 50.1 | 32.2 | 42.3 | 48.1 | 42.3 | 30.1 | 39.8 |
| EG | 93.5 | 100.1 | 89.6 | 76.5 | 68.3 | 81.0 | 83.3 | 76.4 | 74.6 | 93.8 |

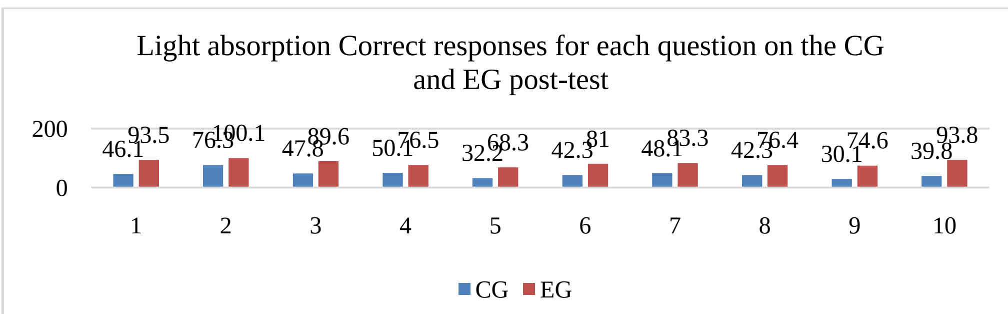


**Figure 7**:Retention of light: The rate (%) of right reactions for each inquiry in the post-test for the Exploratory Gathering (EG) and Control Gathering (CG)

For example, the seventh inquiry pose, "Photovoltaic shells: a) ingest all sun powered energy that falls on them and convert it into heat, mechanical energy, or power, or b) retain a part of light energy and convert it into heat." c) ingest some light energy and change it into electrical energy; d) retain some light energy and change it into mechanical energy.

## VI. Analysis – Synthesis of light

Both the pre-test and post-test mean scores were 4.80 (standard deviation 1.80) and 8.75 (standard deviation 1.02).

**Table 8**: Examination - Combination Of Light: The Portion Of Right Reactions For Each Inquiry In The Post-Trial Of The Exploratory Gathering (Eg) And Control Gathering (Cg)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CG | 76.2 | 72.2 | 42.1 | 54.3 | 42.1 | 38.1 | 35.9 | 55.8 | 34.2 | 34.2 |
| EG | 100.2 | 98.0 | 83.1 | 93.5 | 82.8 | 81.0 | 78.9 | 91.4 | 74.2 | 93.4 |

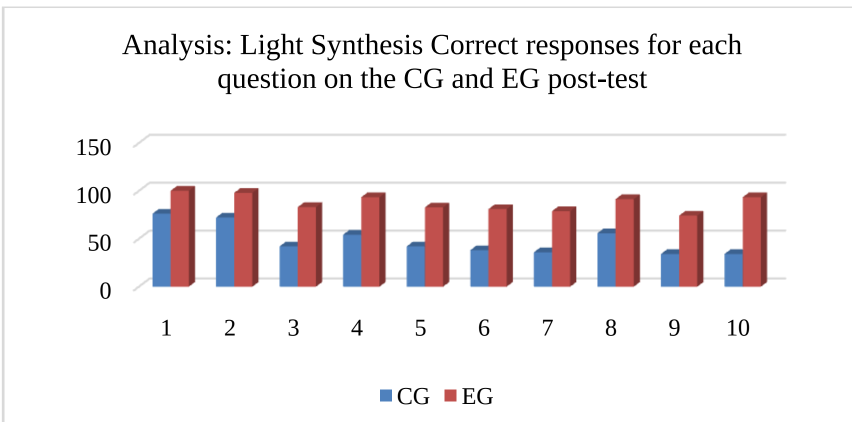


**Figure 8**: Rate (%) Of Right Responses For Each Inquiry In The Post-Test For The Benchmark Group (CG) And The Exploratory Gathering (EG) Examination - Amalgamation Of Light

"Rainbow: a) should be visible just when the sky is loaded up with water fume, b) just shows up at noontime, c) just shows up in the first part of the day, d) all eyewitnesses see something very similar at a given time," is the eighth inquiry, for example.

## VII. Polarization of light

The mean score was 4.12 (standard deviation 1.30) for the pre-test and 8.43 (standard deviation 0.93) for the post-test.

**Table 9**: Light Polarization: The Proportion of Precise Reactions to Each Question in the Post-Test for the Benchmark Group (Cg) and the Exploratory Gathering (Eg)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| CG | 57.9 | 56.2 | 40.3 | 38.3 | 35.8 | 37.9 | 40.1 | 37.8 | 34.2 | 36.2 |
| EG | 98.0 | 93.5 | 83.1 | 81.0 | 81.2 | 81.2 | 79.5 | 87.3 | 74.3 | 89.2 |

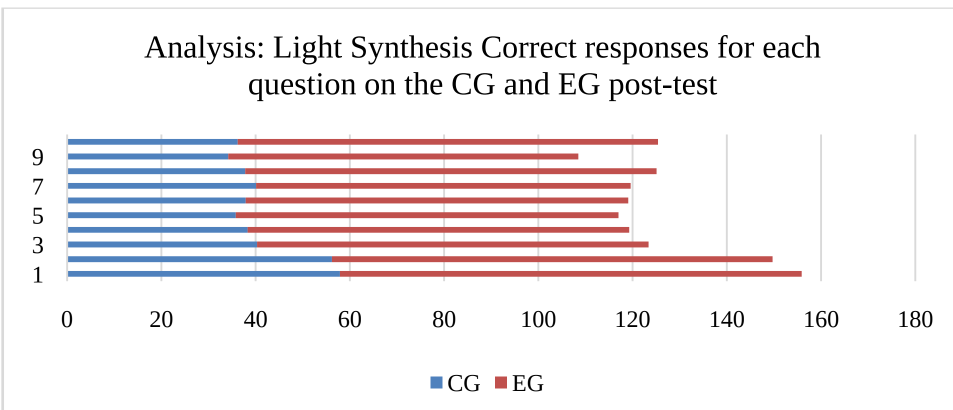


**Figure 9:** Polarization Of Light: Rate (%) Of Right Reactions For Each Inquiry In The Post-Test For The Trial Gathering (EG) And Control Gathering (CG)

For example, the seventh inquiry pose, "Our Polaroid glasses help to more readily see the ocean and frigid mountains in light of the fact that: a) they "cut" UV light; b) they lessen how much light that falls on the eyes; c) they "cut" infrared radiation; and d) they "slashed" the enraptured part of light that is pondered snow or water."

## 6.2.REMARKS ON RESULTS PER UNIT

Following a pedagogical intervention, students experience light as both particles and waves at the same time. Be aware that light is both photons and waves in the quantum theory and that photons are particles with wave characteristics in the electromagnetic theory. At last, they comprehend the origin of every phenomenon they have examined. Following their experience learning with the multimedia software, understudies' scores for the establishment of a blended showing approach (tests in the research center and programming reenactments) show that they are very much arranged towards it.. Notwithstanding the way that well their examinations have gone with intelligent media programming, understudies actually favor a philosophy for their investigations overall and value having an educator there in the homeroom. Rather than conventional on location guidance, understudies total a survey at the finish of the course to assess the instructive application that was utilized as an educating device.

## 7. CONCLUSIONS AND IMPLICATIONS

Creating tenable conceptual models, or "frames" around which different physical phenomena can be interpreted and described, is one of physics' primary objectives. The search for a workable model for the phenomenon of light is arguably the most notable example of this. We know about the swaying among molecule and wave models in individuals' originations of the idea of light. Molecule and wave characteristics are joined to make the traits of light.Given that the following question has no answer:"Is it possible for a critical experiment to support one theory while eliminating another?" These days, we think that light is dual in nature. It is challenging to illustrate or visualise this duality. The main autonomous ideas that people can imagine are particles and waves.

As indicated by the examination, this is one of the main pressing concerns with how the point is educated. According to the research, teaching light to students who lack the necessary knowledge in physics and maths can be challenging. Following the introduction of a new didactic method, most questions on the post-test had answers with percentages of right answers above 85%, and the final test, which was given a month later, yielded results that were nearly identical. These students were in upper secondary education. The post-test results for the Trial Gathering (EG) and Control Gathering (CG) showed an extremely huge level of distinction. The instructive mediation's original angles include:

- The conversion of quantum standards from science to education
- The endeavour to teach secondary school pupils (high school) post-classical physics through the use of dynamic microcosm visualisation and simulation.
- Combining traditional experimental (lab) learning with software (computer)
- encouraging the integrative and cohesive character of science as acknowledged by contemporary theories and fostering a favourable perception of physics.

Recollect that the review was directed in a controlled setting as opposed to during a commonplace secondary school study hall meeting.While this may seem like a limitation, it actually strengthens the assessment results by adding more experimental rigour since it was planned to wipe out any factors that could slow down the examination's lead, (for example, the quantity of study hours or the observing of showing materials utilized in the exploration). The discoveries point us toward future bearings for the review.

**REFERENCES**

1. *Colin, P. &Viennot, L.: 2000, 'Using two Models in Optics: Student's difficulties and suggestions for teaching', Physics Education Research, American Journal of Physics, Supplement.*
2. *Driver, R., Squires, A., Rushworth, P. & Wood-Robinson, V.: 2000, Making Sense of Secondary Science: Research into Children's Ideas, Routledge, London.*
3. *Rutherford, M.: 2000, 'Models in the Explanation of Physics: The Case of Light', in Gilbert, J. & Boulter, C. (eds.), Developing Models in Science Education, Kluwer Academic Publishers, Dordrecht.*

4. *N. Voudoukis, "Application of Post - Classical Models of Light in Secondary and Higher Education through Experiments and Simulations - Design, Assessment and Proposals" Ph.D. dissertation, National University of Athens, Greece, 2013.*
5. *Adamson, Peter (2006). "Al-Kindi¯ and the reception of Greek philosophy". In Adamson, Peter; Taylor, R.. The Cambridge companion to Arabic philosophy. Cambridge University Press.*
6. *Hogendijk, Jan P.; Sabra, Abdelhamid I., eds. (2003). The Enterprise of Science in Islam: New Perspectives. MIT Press.*
7. *Nader El-Bizri (2007). "In Defence of the Sovereignty of Philosophy: al-Baghdadi's Critique of Ibn al-Haytham'sGeometrisation of Place". Arabic Sciences and Philosophy.*
8. *J.E. Greivenkamp (2004). Field Guide to Geometrical Optics. SPIE Field Guides vol. FG01. SPIE.*
9. *J. Goodman (2005). Introduction to Fourier Optics (3rd ed.). Roberts & Co Publishers.*
10. *C.H. Townes (2003). "The first laser". In Laura Garwin; Tim Lincoln (eds.). A Century of Nature: Twenty-One Discoveries that Changed Science and the World. University of Chicago Press*
11. *D. Atchison & G. Smith (2000). Optics of the Human Eye.*
12. *Sidney F. Ray (2002). Applied Photographic Optics: Lenses and Optical Systems for Photography, Film, Video, Electronic and Digital Imaging. Focal Press.*
13. *New York Times Staff (2004). The New York Times Guide to Essential Knowledge. Macmillan.*
14. *El-Bizri, Nader (2010). "Classical Optics and the Perspectiva Traditions Leading to the Renaissance". In Hendrix, John Shannon; Carman, Charles H. (eds.). Renaissance Theories of Vision (Visual Culture in Early Modernity).*
15. *Balabanoff, M. E., Al Fulaiti, H., Bhusal, S., Harrold, A., & Moon, A. C. (2020). An exploration of chemistry students' conceptions of light and light-matter interactions in the context of the photoelectric effect. International Journal of Science Education.*

16. *Greentree, A. D., Tahan, C., Cole, J. H., &Hollenberg, L. C. (2006). Quantum phase transitions of light. Nature Physics,*
17. *Molloy, J. E., & Padgett, M. J. (2002). Lights, action: optical tweezers. Contemporary physics.*
18. *Lenton, I.C., Armstrong, D.J., Stilgoe, A.B., Nieminen, T.A. and Rubinsztein-Dunlop, H., 2020. Orientation of swimming cells with annular beam optical tweezers. Optics Communications*
19. *Dholakia, K., &Zemánek, P. (2010). Colloquium: Gripped by light: Optical binding. Reviews of modern physics.*
20. *Lerner, A., &Shashar, N. (2014). Polarized light and polarization vision in animal sciences (Vol. 2, p. 5). G. Horváth (Ed.). Berlin: Springe.*