EFFECT OF CONCEPT MAPPING STRATEGY IN PROBLEM-BASED LEARNING ON ACHIEVEMENT AND ATTITUDE TOWARDS PHYSICS AMONG HIGHER SECONDARY SCHOOL STUDENTS

Thesis submitted to the University of Calicut
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DOCTOR OF PHILOSOPHY IN EDUCATION

By

SUNIL K

Under the Supervision of

Dr. Manoj Praveen G
Associate Professor

DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

2025

DECLARATION

I hereby declare that the work presented in the thesis entitled "**EFFECT OF CONCEPT MAPPING STRATEGY IN PROBLEM-BASED LEARNING ON ACHIEVEMENT AND ATTITUDE TOWARDS PHYSICS AMONG HIGHER SECONDARY SCHOOL STUDENTS**" is based on the original work done by me under the guidance of **Dr. Manoj Praveen G**, Associate Professor, Department of Education, University of Calicut and has not been included in any other thesis submitted previously for the award of any Degree, Diploma, Title or Recognition before. The contents of the thesis are undergone plagiarism check using iThenticate software at C.H.M.K. Library, University of Calicut, and the similarity index found within the permissible limit. I also declare that the thesis is free from AI generated contents.

Sunil. K
(Research Scholar)

Dr. Manoj Praveen G
(*Supervising Teacher*)

Place: C.U. Campus
Date: 08.12.2025

Dr. Manoj Praveen G.
Associate Professor
Department of Education
University of Calicut

Certificate

I, **Dr. Manoj Praveen G,** do hereby certify that this thesis entitled **EFFECT OF CONCEPT MAPPING STRATEGY IN PROBLEM-BASED LEARNING ON ACHIEVEMENT AND ATTITUDE TOWARDS PHYSICS AMONG HIGHER SECONDARY SCHOOL STUDENTS** is a record of bonafide study and research carried out by **Mr. Sunil. K.**, for the degree of **Doctor of Philosophy in Education, University of Calicut**, under my supervision and guidance and that no part thereof has been presented before for any other Degree, Diploma, Title or Recognition.

Place: C.U. Campus
Date: 08-12-2025

Dr. MANOJ PRAVEEN G
(*Supervising Teacher*)

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Place: C.U. Campus **SUNIL K**

Date:

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ABSTRACT

EFFECT OF CONCEPT MAPPING STRATEGY IN PROBLEM-BASED LEARNING ON ACHIEVEMENT AND ATTITUDE TOWARDS PHYSICS AMONG HIGHER SECONDARY SCHOOL STUDENTS

പ്രശ്നാധിഷ്ഠിത പഠനത്തിൽ കൺസെപ്റ്റ്മാപ്പിങ്ങ് തന്ത്രം ഫിസിക്സ് പഠന നേട്ടത്തിലും സമീപനത്തിലും ഹയർ സെക്കൻഡറി സ്കൂൾ വിദ്യാർത്ഥികളിൽ ഉണ്ടാക്കുന്ന സ്വാധീനം

Science education plays a vital role in developing critical thinking, inquiry, and systematic reasoning among learners. As science and technology rapidly advance, traditional teaching methods that promote passive learning and rote memorisation are no longer adequate (Gorghiu et al., 2015). Problem-Based Learning (PBL), an instructional method centred on real-world problems that require critical thinking, emerged to overcome such limitations (Barrows, 2000). Integrating Concept Mapping into PBL offers a more innovative approach, enabling students to visualise prior knowledge, identify learning gaps, and organise new information more meaningfully.Research evidence shows that concept mapping enhances learning quality and supports PBL by fostering active participation, creativity, and improved assessment performance (Johnstone & Otis, 2006; Zwaal & Otting, n.d.; Chan, 2017). In this study, a quasi-experimental pretest–posttest comparison-group design was adopted to investigate the effect of Concept Mapping in PBL on achievement and attitude towards Physics among Higher Secondary School students. The sample consisted of 100 XI-standard students, divided into an experimental group (PBL with Concept Mapping) and a comparison group (PBL without Concept Mapping). Instructional strategy was the independent variable; achievement and attitude were dependent variables; and Nonverbal Intelligence and Logical–Mathematical Intelligence served as covariates. The tools included Standard Progressive Matrices, a Logical–Mathematical Intelligence Test, lesson transcripts for both instructional strategies, an Achievement Test in Physics, and a Physics Attitude Scale. Data were analysed using t-test, ANCOVA, Two-Way ANOVA, and Scheffé's Post Hoc Test.

Findings revealed a significant effect of the instructional strategy on both achievement and attitude towards Physics, even after controlling for intelligence variables. A significant main effect of strategy and Logical–Mathematical Intelligence was found, with no interaction effect. Students taught through Concept Mapping integrated with PBL showed notably higher achievement and a more positive attitude compared to those taught through PBL alone.The study concludes that Concept Mapping enhances the effectiveness of PBL in Physics at the Higher Secondary level. It recommends wider adoption of this instructional strategy in schools and encourages further research across other subjects, educational levels, and curricular contexts in India.

Keywords: Instructional Strategy, Problem-Based Learning (PBL), Concept Mapping, Achievement in Physics, Attitude towards Physics, Higher Secondary School Students.

Dr. Manoj Praveen G,
Supervising Teacher.

Sunil.K
Research Scholar.

<u>സംഗ്രഹം</u>

പ്രശ്നാധിഷ്ഠിത പഠനത്തിൽ കൺസെപ്റ്റ് മാപ്പിംഗ് തന്ത്രം ഫിസിക്സ് പഠന നേട്ടത്തിലും സമീപനത്തിലും ഹയർസെക്കൻഡറി സ്കൂൾ വിദ്യാർത്ഥികളിൽ ഉണ്ടാക്കുന്ന സ്വാധീനം

ഡോ. മനോജ് പ്രവീൺ ജി
മാർഗദർശി

സുനിൽ. കെ
ഗവേഷക വിദ്യാർത്ഥി

പാഠ്യപദ്ധതിയിൽ ശാസ്ത്രത്തെ ഉൾപ്പെടുത്തുന്നത് വിദ്യാർഥികളെ വിമർശനാത്മകമായി ചിന്തിക്കുന്നവരാക്കി മാറ്റുകയും അവരുടെ ബുദ്ധിയെ രൂപപ്പെടുത്തുകയും ചിന്താശേഷിയിൽ കൂടുതൽ സൂക്ഷ്മവും ക്രമബദ്ധവുമായ രീതിയിലേക്ക് നയിക്കുകയും അന്വേഷണ മനോഭാവം വളർത്തുകയും ചെയ്യുന്നു. ശാസ്ത്രം മനുഷ്യനെ സമയത്തെയും ദൂരത്തെയും കീഴടക്കാൻ സഹായിച്ചു. ലോകത്തിന്റെ വേഗത്തിലുള്ള പുരോഗതിക്കെല്ലാം അത് അടിത്തറയായി. ശാസ്ത്രവും സാങ്കേതിക വിദ്യയും അതിവേഗം വളർന്നതോടെ ജീവിതത്തിന്റെ എല്ലാ മേഖലകളിലും അത് സ്വാധീനം ചെലുത്തി. നമ്മൾ ജീവിക്കുന്ന ലോകത്തെ ശരിയായി മനസ്സിലാക്കാൻ ശാസ്ത്രത്തിന്റെ നിലവിലെ സ്ഥിതിയും പുരോഗതിയും അറിഞ്ഞിരിക്കേണ്ടത് കാലഘട്ടത്തിന്റെ അനിവാര്യതയാണ്. പഴയ പഠന രീതികളെ കാലാനുസൃതമായി നവീകരിച്ച് നവീനമായ പഠനതന്ത്രങ്ങൾ സ്വീകരിക്കേണ്ടത് ഈ കാലത്ത് അത്യാവശ്യമാണ്. പരമ്പരാഗത അധ്യയന രീതികൾ വിദ്യാർത്ഥികളിൽ പ്രവർത്തനരഹിതത്വം സൃഷ്ടിക്കുകയും പഠനം പരീക്ഷയ്ക്ക് വേണ്ടി കേട്ടറിഞ്ഞ അറിവ് പുനരാവർത്തിക്കുന്ന പ്രവണതയിലേക്ക് ചുരുങ്ങുകയും ചെയ്യുന്നു. പ്രശ്നാധിഷ്ഠിത പഠനം എന്നത് യഥാർത്ഥ ജീവിത പ്രശ്നങ്ങളെ അടിസ്ഥാനമാക്കി വിമർശനാത്മകമായി ചിന്തിച്ച് അവ പരിഹരിക്കാൻ ആവശ്യമായ കഴിവുകൾ കൈവരിക്കുന്നതിനുള്ള വിദ്യാഭ്യാസ രീതിയാണ്. നിരർത്ഥകമായി ഓർമ്മപ്പെടുത്തൽ, പ്രവർത്തന രഹിത പഠനം, പ്രായോഗികത ഇല്ലാത്ത സിദ്ധാന്തം, സൃഷ്ടിപരമായ കഴിവുകളുടെ അഭാവം തുടങ്ങിയവ ഇല്ലാതാക്കുന്നതിനുള്ള ഒരു മാർഗ്ഗമാണ് പ്രശ്നാധിഷ്ഠിത പഠനം. പ്രശ്നാധിഷ്ഠിത പഠനത്തിൽ കൺസെപ്റ്റ് മാപ്പിംഗ് ഉൾപ്പെടുത്തുന്നത് ശാസ്ത്ര വിദ്യാഭ്യാസത്തിന്റെ പുരോഗമനത്തിന് അനുയോജ്യമായ നവീന രീതിയാണ്. വിദ്യാർത്ഥികൾക്ക് അവരവരുടെ മുൻധാരണയിലുള്ള അറിവ് കൺസെപ്റ്റ് മാപ്പിങ്ങിന്റെ രൂപത്തിൽ ദൃശ്യവൽക്കരിക്കാനും പ്രശ്നത്തെ മനസ്സിലാക്കുന്നതിനും അന്വേഷണ ബുദ്ധി ഉണ്ടാക്കുന്നതിനും പ്രശ്നാധിഷ്ഠിത പഠനത്തിൽ കൺസെപ്റ്റ് മാപ്പിങ് ഉപയോഗിക്കുന്നതിലൂടെ സാധിക്കുന്നു. കൺസെപ്റ്റ് മാപ്പിംഗ് ഉൾപ്പെടുത്തിയ പ്രശ്നാധിഷ്ഠിത പഠനത്തിലൂടെ വിദ്യാർത്ഥികളുടെ പഠനനിലവാരം മെച്ചപ്പെടുന്നതായി വിവിധ പഠനങ്ങൾ തെളിയിക്കുന്നു. പഠനത്തിലും ആവർത്തനത്തിലും കൺസെപ്റ്റ് മാപ്പിംഗ് ഉപയോഗിക്കുന്ന വിദ്യാർത്ഥികൾ അത് ഉപയോഗിക്കാത്തവരെക്കാൾ മികച്ച പ്രകടനം കാഴ്ചവെക്കുന്നതായും, കൺസെപ്റ്റ് മാപ്പിംഗ് തന്ത്രം പ്രശ്നാധിഷ്ഠിത പഠനപ്രക്രിയ മെച്ചപ്പെടുത്തുന്ന ഉപകരണമാണെന്നും പഠനങ്ങൾ തെളിയിക്കുന്നു.

പ്രശ്നാധിഷ്ഠിത പഠനത്തിൽ കൺസെപ്റ്റ് മാപ്പിംഗ് ഉപയോഗിക്കുന്നത് വിദ്യാർത്ഥികളെ പഠനത്തിലേക്ക് കൂടുതൽ പ്രേരിപ്പിക്കുകയും സജീവമായി പങ്കെടുക്കാൻ പ്രാപ്തരാക്കുകയും സൃഷ്ടിപരമായ കഴിവുകൾ വളർത്തുകയും ചെയ്യുന്നു. ഈ പഠനം പ്രശ്നാധിഷ്ഠിത അധ്യയനത്തിൽ കൺസെപ്റ്റ് മാപ്പിങ് തന്ത്രം ഉപയോഗിക്കുന്നതിലൂടെ ഫിസിക്സ് പരീക്ഷയിലുള്ള വിജയം, ഫിസിക്സിനോടുള്ള സമീപനം എന്നിവയ്ക്കുള്ള സ്വാധീനം പരിശോധിക്കുന്നു. പ്രീ ടെസ്റ്റ് പോസ്റ്റ്

ടെസ്റ്റ് കമ്പാരിസൺ ഗ്രൂപ്പ് രൂപകല്പനയാണ് ഈ പഠനത്തിൽ ഉപയോഗിച്ചിരിക്കുന്നത്. പ്ലസ് വൺ ക്ലാസിലെ 100 വിദ്യാർത്ഥികളെ ഉൾപ്പെടുത്തി രണ്ട് വിഭാഗങ്ങളാക്കി 50 വിദ്യാർത്ഥികൾ പരീക്ഷണ ഗ്രൂപ്പിലും 50 വിദ്യാർഥികൾ താരതമ്യ ഗ്രൂപ്പിലും ഉൾപ്പെടുത്തിയിരിക്കുന്നു. അധ്യയന രീതി (കൺസെപ്റ്റ് മാപ്പിംഗ് ഉൾപ്പെടുത്തിയ പ്രശ്നാധിഷ്ഠിത പഠനം / കൺസെപ്റ്റ് മാപ്പിംഗ് ഉൾപ്പെടുത്താത്ത പ്രശ്നാധിഷ്ഠിത പഠനം) സ്വതന്ത്ര ചരങ്ങളാക്കി ഫിസിക്സ് പരീക്ഷയിലുള്ള വിജയവും ഫിസിക്സിനോടുള്ള സമീപനവും ആശ്രിത ചരങ്ങൾ ആക്കി നോൺവെർബൽ ഇന്റലിജൻസ്, ലോജിക്കൽ മാത്തമാറ്റിക്കൽ ഇന്റലിജൻസ് എന്നിവ നിയന്ത്രിത ചരങ്ങൾ ആയും ഈ പഠനത്തിൽ സ്വീകരിക്കുന്നു. പഠനത്തിനായി നോൺവെർബൽ ഇന്റലിജൻസ് ടെസ്റ്റ്, ലോജിക്കൽ മാത്തമാറ്റിക്കൽ ഇന്റലിജൻസ് ടെസ്റ്റ്, കൺസെപ്റ്റ് മാപ്പിംഗ് പ്രശ്നാധിഷ്ഠിത പഠനത്തിൽ ഉൾപ്പെടുത്തിയ പാഠ്യപദ്ധതി, കൺസെപ്റ്റ് മാപ്പിങ്ങ് പ്രശ്നാധിഷ്ഠിത പഠനത്തിൽ ഉൾപ്പെടുത്താതെയുള്ള പാഠ്യപദ്ധതി, ഫിസിക്സിലെ വിജയം പരിശോധിക്കുന്ന തിനുള്ള പരീക്ഷ, ഫിസിക്സിനോടുള്ള സമീപനം പരിശോധിക്കുന്നതിനുള്ള സ്കെയിൽ എന്നീ ഉപകരണങ്ങൾ പഠനത്തിനായി ഉപയോഗിച്ചു. ടി ടെസ്റ്റ്, അൻകോവ, ടു വേ അനോവ, ഷഫേയ്സ് പോസ്റ്റ് ഹോക് ടെസ്റ്റ് എന്നിവ കണക്കുകൂട്ടൽ രീതികളായി പഠനത്തിൽ ഉപയോഗിച്ചിരിക്കുന്നു. അധ്യയന രീതി (പ്രശ്നാധിഷ്ഠിത പഠനത്തിൽ കൺസെപ്റ്റ് മാപ്പിംഗ് ഉൾപ്പെടുത്തിയ പാഠ്യപദ്ധതി/പ്രശ്നാധിഷ്ഠിത പഠനത്തിൽ കൺസെപ്റ്റ് മാപ്പിങ് ഉൾപ്പെടു ത്താത്ത പാഠ്യപദ്ധതി) ഫിസിക്സ് പരീക്ഷ വിജയത്തിലും ഫിസിക്സിനോടുള്ള സമീപനത്തിലും , നോൺവെർബൽ ഇന്റലിജൻസ് ലോജിക്കൽ മാത്തമാറ്റിക്കൽ ഇന്റലിജൻസ് എന്നിവ കോ വേരിയേറ്റ്സ് ആയി പരിഗണിക്കുമ്പോൾ നിർണായക സ്വാധീനം ചെലുത്തുന്നതായി ഈ പഠനം കണ്ടെത്തി. ഈ പഠനത്തിൽ പ്രധാന സ്വാധീനം മാത്രമേ കണ്ടെത്തിയുള്ളൂ സംയുക്ത സ്വാധീനം ഉണ്ടായിട്ടില്ല. കൺസെപ്റ്റ് മാപ്പിംഗ് തന്ത്രം ഉൾപ്പെടുത്തിയ പ്രശ്നാധിഷ്ഠിത പഠനം ഹയർ സെക്കൻഡറി വിദ്യാർത്ഥികളുടെ ഫിസിക്സിലെ പരീക്ഷാ വിജയം, ഫിസിക്സിനോടുള്ള സമീപനം എന്നിവയിൽ നല്ല സ്വാധീനം ചെലുത്തുന്നതായി ഈ പഠനം തെളിയിക്കുന്നു, പരീക്ഷണ ഗ്രൂപ്പിൽ നൽകിയ ഈ നവീന അധ്യയന രീതി മൂലം വിദ്യാർത്ഥികൾ ഫിസിക്സിൽ കൂടുതൽ മികച്ച വിജയം, ഫിസിക്സിനോടുള്ള പോസിറ്റീവ് സമീപനം എന്നിവ പ്രകടിപ്പിച്ച തിനാൽ വിദ്യാഭ്യാസ രംഗത്ത് ഈ രീതി ഉപയോഗിക്കണമെന്ന് ശുപാർശ ചെയ്യുന്നു. കൂടാതെ മറ്റു വിഷയങ്ങളിലെയും മറ്റ് വിദ്യാഭ്യാസ നിലവാരങ്ങളിലെയും ഫലപ്രാപ്തി പരിശോധിക്കുന്ന തിന് ഈ രീതി ഉപയോഗിക്കണമെന്നും ഗവേഷണങ്ങൾ തുടരണമെന്നും നിർദ്ദേശിക്കുന്നു..

പ്രധാന വാക്കുകൾ: അധ്യയന രീതി, പ്രശ്നാധിഷ്ഠിതപഠനം, കൺസെപ്റ്റ് മാപ്പിങ്, ഫിസിക്സ് പരീക്ഷ വിജയം, ഫിസിക്സിനോടുള്ള സമീപനം, ഹയർ സെക്കൻഡറി വിദ്യാർത്ഥികൾ.

Dr. Manoj Praveen G.

SUNIL.K

Chapter 1
INTRODUCTION

- ***Setting of the Problem***
- ***Need and Significance of the Study***
- ***Statement of the Problem***
- ***Operational Definition of Key Terms***
- ***Objectives***
- ***Hypotheses***
- ***Methodology***
- ***Scope and Delimitation***
- ***Organisation of the Report***

INTRODUCTION

"If we teach today's students as we taught yesterday's, we rob them of tomorrow."

- Dewey (1944)

With limitless time to experiment as well as inexhaustible resources at her disposal, nature produces master pieces of astounding beauty. Mankind has continually striven to know more about the Environment, the Earth, and the cosmos itself. Man's search for truth is characterised by appeal to custom, tradition, authority and personal Experience and also to syllogistic reasoning. Man confronts nature, compelling her to reveal her secrets, and for that, he makes systematic attempts. By his persistent efforts, careful experimentation and exact reasoning, man has collected a mass of tested information, which we call Science. And it is through Education that this information or science is to be imparted to future generations. Science can be considered as the concerted human effort with an aim to understand, or say to understand better, the evolution of the natural world and how the natural world works in its own way, with observable physical evidence as the basis of that acquired understanding. It is mainly done through careful and scientific observation of natural phenomena, and/or through systematic experimentation which tries to stimulate the natural processes. The discipline science, broadly and philosophically considered, is reasoning from evidence to conclusions. Thus, in short, we can say that Science is an 'intellectual human activity' which is mainly concerned with integrating as well as coordinating, in a scientific and systematic way, new informations with existing as well as ever-expanding reservoir of information. This integration in fact provides a more complete explanation and details of the natural world in which we humans live. This ever expanding reservoir of informations available to scientists and society is made available by sourcing from many different fields of exploration.

In terms of the policy, the Government of India adopted in 1968, “It is an inherent obligation of a great country like India, with its tradition of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science, which is probably making the greatest enterprises today”. The way of teaching science, like any other subject, can be shown valid for various reasons. In fact the very nature of the subject justifies its inclusion in the curriculum. The discipline ‘science’ equips pupils to cultivate the ability to think and shape their own intellect, enabling them with better reasoning skills; to be more careful and systematic in reasoning. It makes available a unique training in truth, indoctrinates a spirit of inquiry, develops the ability to know the unknown and gives them the strength to face failures. The report put forward by the 1964-66 education commission laid much importance on science based education. In its own words, “There is one thing about which we feel with no doubt of hesitation, that is, science-based education in coherence with Indian culture and values can alone provide the foundation as an instrument for the nation’s progress, security and welfare”. In its recommendation on “education and productivity”, the commissions further mention that “science education should become an integrate part of education, ultimately some study of science should become a part of all courses in humanities and social science”. The recommendations made by UNESCO’s international commission about the teaching of science as follows “science must become an essential component in educational enterprise, it must be incorporated into all educational activity, intended for children, young people and adults in order to help the individual to control social energies as well as national and productive one’s (Yadav, 1992)

The rapid growth of science and technology is influencing almost all walks of life. This rapid growth is resulting in the production of entirely new materials.

Science has always acted as a spring board for all the progress taken place in our world, and we human beings have been able to conquer time and distance with the help of rapidly growing science. Thus it is no exaggeration to say that, right now, science shows dominance in every field of activity. Science has improved the quality of living in all possible ways and has saved mankind from excessive fear and ignorance. The technological developments have always sought to explore, multiply and ease out the possibilities of affording more convenient and comfortable living conditions. Thus we can say, from cradle to the grave, scientific inventions and discoveries have inseparably woven themselves into the very fabric of human existence.

As it is a human endeavor, science is strongly dependent on human motivation. The human motivation of scientific endeavor is not difficult to find. Firstly, there is the never ending need for knowledge for man to master the environment in which he lives in. Thus, it is clear that science is valued mainly for its practical advantages which has direct influence in all walks of our life. Hence, some amount of knowledge of the present position and progress of science is need of the hour to acquire an adequate understanding of the world in which we all live. Our mode of life is mostly dependent on the scientific advancement of last half of the century or so. The old concept of science teaching has to be changed according to the needs of the present day, with innovative teaching strategies.

According to Redden (1996) "Education is the deliberate and systematic influence, exerted by the mature person upon opinion the immature through instruction, discipline and harmonious development of physical, intellectual, aesthetic social and spiritual powers of human being according to individual and social need directed towards the union of the educand and his creator as the ends".

The above definition explains the aim of education, which is to be achieved in school through the formal training of different subjects. In education, each subject in turn has some general and specific objectives to achieve. But to satisfy the prerequisites of this era of knowledge as well as the objectives of each subject, the question of "how to teach" needs to be considered seriously in the different levels of the formal education system. If we consider a class and try finding an answer to the question “What percentage of the students within each class are self-directed, engaged, and active?”, it will be clear that each year, fewer students become active and motivated learners. More of them join the group of passive learners. Knowledge cannot be transferred from one person to another unless a trigger has been provided. Improved achievement and development of higher-order thinking skills (HOTS), such as self-directed learning skills, analyzing, creating and problem-solving ability skills, are needed in the present rapidly advancing world. Moreover, from the perspective of the teaching profession, pedagogical concerns are important to be addressed as the teacher has to create a suitable environment that not only facilitates learning but also improves the other extended skills of a learner.

In student-centered learning, students learn to decide what they need to know. By making use of the essential experience obtained and guided practice carried out, the students will acquire full independence, with the teacher mainly acting as a facilitator. The emphasis is on the active student participation and acquisition of necessary information and skills gained by students which are suitable to their ability, level of experience, and educational needs. Constructivist approach of learning is a student centered approach which suggests that conceptual developments in the learners should be encouraged and facilitated by various activities in which students do actively engage in comprehending the material; creating their own conceptual frameworks; confronting, presenting and defending various other relevant perspectives; connecting novel concepts to old concepts; and adopting strategies which improves both metacognition (i.e., being aware of and monitoring one's own thinking process) and higher order thinking skills (e.g., analysis, synthesis, evaluation etc) as well. The constructivist approach gives the learners a chance to formulate or construct knowledge of their own by interrelating it with the already existing knowledge, i.e., prior knowledge in their cognitive system. And it is important to note that the method of teaching put forward by the constructivist approach is purely learner-centred, which prepares the students to apply the education in real-life situations. Such methods or approaches can be seen to hold both scientific validity and pedagogic utility.

"Instruction should be geared not just toward imparting a knowledge base, but toward developing reflective, analytical, creative, and practical thinking with a knowledge base. Students learn better when they think to learn ...They also learn better when teaching takes into account their diverse styles of learning and thinking" (Sternberg, 1998)

National Curriculum Framework (2005) emphasizes the learning process through activities, discovery and exploration in a learner-centered manner. National Curriculum Framework for Teacher Education (2009) highlights that a teacher is a facilitator of children's learning process, assisting them in the process of constructing knowledge. In this process, the teacher is seen as a co-constructor of knowledge. National Education Policy (2020) India highlights the concept of student-oriented pedagogies as it provides a crucial space for psychological development and learning of students. The study “A Meta-Analysis on Instructional Applications of Constructivism in Science and Technology Teaching: A Sample of Turkey” by Ural and Bümen (2018) explains the importance of student-centred activities and finds that to are more effective than traditional activities for increasing academic achievement. This study shows that the learners learn better by constructing solutions to complex, problematic and open-ended activities compared to listening to lectures in a passive manner.

Traditional teaching strategies generate a real passivity among students, who are placed in the position of ready-made knowledge consumers, their only effort being oriented to secure and, subsequently, reproduce the knowledge in the context of evaluation tests (Gorghiu et al., 2015). Problem-Based Learning can be considered as an efficient teaching-learning approach through which the learners may be helped to acquire competences in Science, since PBL represents an educational method in which real-world problems are considered in such a way that learners think critically to achieve skills for solving the proposed problem. The concept of PBL arises out of the necessity of eliminating rote memorisation, passive learning, theoretical knowledge with no practice, lack of creativity and skills, etc., among the current generation learners (Barrows, 2000). PBL approach shows the difference between being “book-smart” and having a more holistic, practical approach coupled with knowledge. PBL strategy can be regarded as a powerful shift from outdated ways of teaching, which are more often lecture-based. It has been used for 50 years, and it appears to be the most powerful constructivist pedagogical structure. Various studies have shown that PBL is effective in improving learner skills as well as applying them in problematic situation which requires problem-solving abilities. The primary aim of PBL is not learning for knowledge but learning for capability (Gallagher, 1997). Problem-based learning (PBL) can be considered as a student-centred pedagogy in which students actively learn about a subject through the experience of solving open-ended problems (Savery, 1995). In a PBL environment, a learner, in the process of learning, comes across an ill-structured problem; this problem acts as a focus or stimulus to apply problem-solving abilities/skills (Barrows, 1996; Torp & Sage, 2002; Hmelo-Silver, 2004). In the process, the learner may have to deal with information and mechanisms needed to solve the problem. It involves the students to identify and dust off their prior knowledge and skills and apply them to solve ill-structured problem in a PBL environment. It is in this situation; contextualization of learning takes place (Sangestani & Khatiban, 2013). In short, we can say, the students are provided with a situation to conduct research, integrate the theoretical knowledge they have as well and apply it to get a solution for the given problem (Savery, 2006). In PBL, a relevant problem is introduced as a start and thereby it follows with investigation of the solution, resulting in progressive learning. However, the effectiveness of PBL mainly depends on student engagement, the PBL environment created by the teacher and the suitability of the provided ill-structured problem.

Problem-based learning can be used as an effective strategy in most teaching methods, but adapts well in multidisciplinary and interdisciplinary teaching and learning situations (Erdogan, 2015; Tan, 2003). This problem-based approach focuses on self-directed learning methods that are supported by teacher-guided activities. Students are exhorted to analyse the given problems, find appropriate materials or resources, utilise ICT tools and develop the skills of lifelong learning and independent study to come up with the best solution (Moallem et al., 2019). Also, students in a PBL environment take the responsibility for their learning by themselves (Kadir et al., 2016). The main feature of PBL is its nature of mutual collaboration and group work, as well as personal reflection, as one of its key aims is to cultivate the skill of independent lifelong learning. By working in groups, students will be able to recognize what they know already, what they want to know further, how and where to gain new information which will lead to obtaining the solution of given problem. In PBL, the role of instructor (called as the tutor in PBL) is to facilitate learning by supporting and guiding the students in learning process, and monitoring the process of learning carefully. The instructor (or say tutor) is required to shape students' confidence to accept the given problem, and motivate the students towards finding a solution for it by guiding them.

Implementing Concept Mapping Strategy in Problem-Based Learning of science can be viewed as an innovation in the course of the continuous evolution of science education. Concept mapping has been implemented in problem-based learning in medical and nursing education to enhance the quality of students' learning processes (Hsu, 2004; Johnstone & Otis, 2006; Pinto & Zeitz, 1997; Rendas et al., 2006). The reason behind why Concept Mapping strategy is considered to be advantageous for the PBL process is that it promotes the activation as well as elaboration of previous knowledge and students are required to spend more time. By implementing Concept Mapping in the PBL process, students have to visualise their prior knowledge in the form of a concept map, which helps them to separate what is already known from what needs to be researched to better understand the problem and its underlying mechanisms (Johnstone & Otis, 2006). By enabling students in activating and elaborating on previous knowledge, Concept Mapping strategy is anticipated to improve and facilitate the attainment of learning goals. Since, Concept Mapping strategy is anticipated to result in a vigorous and rigorous discussion and thorough analysis of all the concepts, facts, propositions, mechanisms, and interrelationships, we would expect attainment of adequate learning goals in those groups working by employing Concept Mapping strategy in the learning process. An indicator for analyzing the efficacy of Concept Mapping strategy in the PBL approach is the proximity between the student-generated learning goals and those learning goals which are formed by the problem designers. It is the curriculum aims and module objectives which set boundaries for the designers of problem. They may have to function within the limits of the module theme and the module objectives by starting a PBL process that result in realizing the performance goals of that educational unit under consideration. The envisioned learning goals as listed out by the problem designers are not certainly exhaustive or entirely correct, but they are largely considered to be an authentic standard or criterion for assessing the performance of PBL groups. Here, the problem designer, considered as a content expert, is anticipated to be able to articulate the learning goals in a most effective and efficient manner. Research on the correspondence between learning objectives attained by PBL groups and the tutor objectives have showed an average overlap of 64% (Dolmans et al., 1993; Dolmans et al., 1995). The integration of Concept Mapping strategy in online learning methods might develop students as 'self-directed' and 'collaborative' learners to formulate additional learning objectives beyond the ones that were envisioned by the problem designers. These additional learning objectives could come within the scope of the given problem and the learning module or reflect the personal interests of learners. The extend of time spent by learners in the process of learning is an essential prerequisite for creating significant learning gains (Koury et al., 2009). Concept mapping, thus, prevents students from jumping directly to learning goals by spending very little time and attention on the PBL process. Research on the different phases in the PBL process shows that each phase influences the next phase, and learning shows a cumulative pattern (Yew et al., 2011). It provides insight into the time students invest in working on a problem as an indicator of the amount of attention students pay to active cognitive engagement in PBL (Rotgans & Schmidt, 2011; Zwaal & Otting, 2010). Depending on the nature of activities and time spent in the online learning process, Concept Mapping strategy is also likely to influence, in general, the students' opinions about working with PBL approach. It is important to check whether the learners consider Concept Mapping strategy as a quite useful tool to improve the quality of the learning process in PBL approach and whether the exposure and experience with Concept Mapping strategy influence their attitude, achievement, as well as competence in creating concept maps. Research by (Kassab & Hussain, 2010) has shown that the quality of students' concept maps increased as students progressed from year two to year four in a problem-based curriculum.

Setting of the Problem

A learner is the one who is involved in the learning process, gaining new understanding, knowledge, behaviors, values, attitudes, skills, and preferences ("Psychology: The Science of Mind and Behavior 6th Edition," n.d.). There is no doubt that a learner is the cornerstone of societal progress, innovation, and development. But in a traditional information-oriented setup, teachers often act as experts who just convey their knowledge through 'one-sided' lectures. The function of a learner in those types of classrooms is just to passively attend and jot down running notes so that they can memorise them and reproduce them on exams. This is called as "sage on the stage" model, which is useful in presenting large amounts of information. However, it does not support retention of learning and active engagement of the learner. It's high time for the education system to shift from the "sage on the stage "model to the "guide on the side" model, in which the teacher uses his/her skills to engage students in first-hand learning through projects and experiences. In this way, students are transformed from a 'recipient' to a 'participant'. Effective teaching approaches do shift the emphasis from instructor-centred classrooms to learner-centred classrooms. In a learner-centred classroom, the instructor becomes a facilitator in active learning situations in which learners use their existing and prior knowledge and experiences to help them grasp the new knowledge. Here, the learners engage with the content by discussing, analysing, and manipulating it to reconstruct it in meaningful ways. The more engaged students are in the learning process, the more they will retain when they get back to the learning process later, i.e., linking the new information with what they already know, which will help them to retain and recall it in an easy manner. Knowledge that is densely interconnected to other information has improved storage strength in long-term memory and also creates links to more potential retrieval cues. Learner-centred approaches can be viewed as ideal by referring to theories like Self-Determination Theory (Deci & Ryan, 1985), which concludes that the degree to which an individual's behaviour is self-motivated and 'self-determined. The only learning which significantly influences behavior [and education] is self-discovered (Rogers, 1961).

From the perspective of science learning, science has made enormous contributions to the development of the world, irrespective of boundaries. For example, innovations in vaccines, treatments and enabling global communication and information access. Thus, there is no doubt that science has a huge scope, and it is very important to give crucial importance to effective science education. Science education may be defined as the study of the interrelationship between science as a discipline and application principles to its understanding, teaching and learning (Obianuju & Onyinye, 2022). As the world is rapidly changing, and technology and development from different parts of the world may arise in the nick of time and the students' way of acquiring knowledge is also changing at a rapid pace, it exhorts the need of pedagogical practices of science teachers to get improvised for an effective science learning process. Advent of innovative pedagogic methods and the well-prepared teachers can improve the students’ ability towards science learning as well as their achievements in the field of science; this leads more students to continue their studies in various fields of science such as physics, chemistry, biology, technology etc at superior levels and, eventually, resulting in development in the field of science.

Science learning encompasses a wide range of cognitive processes, such as developing scientific reasoning, developing an attitude towards science, epistemological thinking, etc. Hence, we can say that, from the perspective of science learning, the learning process mainly depends on the cognitive engagement of the learner. The canonical perspective of science education, rendering science education similar to the way science is practised in the real world, clearly explains why science has to be taught engagingly. Also, Students learn science in an effective manner through hands-on, activity and inquiry-based learning, rather than merely learning from a textbook. These features of science learning give way for various teaching and learning strategies to be innovated and implemented accordingly. Considering the prevalent style of traditional science teaching, it is high time to introduce and implement new science teaching strategies. In teaching Sciences, the pedagogic practices centred on formalised and excessively generalised presentations should be eliminated and focus should be given to teaching-learning strategies based on action, experimentation, scientific investigation and problem-solving (Drăghicescu et al., 2014). The Scientific Teaching (Handelsman et al., 2007) lists three major pillars of scientific teaching, viz. a) active learning, b) assessment, and c) diversity. These three elements exhort the necessity of ideal teaching strategies covering almost all aspects of science learning process. Problem-Based Learning (PBL), Project-Based Learning, Collaborative Learning, Inquiry-Based Learning, and Student-Teacher-Scientist Partnership (STSP) are such approaches brought as innovations in science learning. Among these, this research paper focuses on an innovation in the Problem-Based Learning approach by integrating it with the concept mapping strategy.

Problem-based learning (PBL) is an effective approach in which the learners are given an reliable problem, generated by problem designers, as the context for an thorough investigation of what they are expected to know. PBL approach exhorts students to work cooperatively in the form of groups to seek out solutions to real-world problems and to become skilful as self-directed learners. Also, PBL promotes metacognition as students generate their strategies for various processes such as information gathering, data analysis, and hypothesis building and testing. In this study, we apply Barell's KWHLAQ strategy in problem problem-solving process of the PBL approach. Later, concept mapping strategy has been implemented in problem-based learning approach as part of research in medical and nursing education to enhance the quality of students' learning processes (Hsu, 2004; Johnstone & Otis, 2006; Pinto & Zeitz, 1997; Rendas et al., 2006). Why Concept Mapping Strategy is considered to be advantageous for the PBL process is that it supports the activation of prior knowledge in which students do visualize their prior knowledge in the form of a concept map, which is useful for them to separate what they already know from what needs to be researched to better understand the problem and its underlying mechanisms making the PBL process more simple, easy and systematic (Johnstone & Otis, 2006). Understanding the effectiveness of the PBL approach (KWHLAQ framework) interlaced with the Concept Mapping strategy in the teaching and learning process will give us valuable insights on how pedagogy should be evolved for improved science education.

Need and Significance of the Study

Study of effectiveness of the PBL approach (KWHLAQ framework) interlaced with the Concept Mapping strategy in the teaching and learning process will give us valuable insights on how pedagogy should be evolved for improved science education. Currently in the field of education, the study of the incorporation of PBL with Concept Mapping can be seen to be limited and hence needs to be considered for advanced research. Also, less research studies are conducted on PBL, Concept Mapping & Concept Mapping with PBL in the Indian context, and hence we can say that it is in its infancy stage in India, resulting in a research gap. Most of the researches are seen to be conducted internationally. Review of past researches has shown that implementation of the KWHLAQ strategy in PBL is rarely done.In the aspect of school education, the effect of PBL, Concept Mapping and PBL with Concept Mapping in Physics is less explored. It is also important to note that most of the past research of Concept mapping strategy in PBL approach is in the field of medicine and engineering.

The researcher thus decided to conduct his research on the topics under consideration for obtaining results which play a potent role in decreasing the research gap and contribute to the development of a new educational strategy. This is why we need a more adaptable and flexible instructional strategy to offer effective educational pathways. Knowledge and information, that are obtained from the investigation of problem, create clear and instant relevance, and significance to the understanding and management of the problem scenario leading to its solution. Thus, problem-based learning (PBL) is an instructional strategy that can be a good candidate among constructivist pedagogies, which aligns with the crucial concerns highlighted above as it is ideally suited for student-centred, self-directed, and individualised learning. PBL can be the pedagogy that can help to establish a teaching learning situation that is a long aspiration of various Indian Education Policies and frameworks like NCF 2005, NCFTE 2009 and NEP 2020. It is evident that the integration of problem-based learning with concept mapping is quite appropriate for these aims and is supported by the ideas put forward by the constructivist approach of learning (Savery & Duffy, 1995).

From the viewpoint of science education, teaching of science at school level has various purposes. Firstly, It must give the student a systematic training in the skill of careful observation, in experimentation and the estimation of the comparative value of results. It should provide a knowledge of the physical world around as well as forces of nature, and must lay a comprehensive foundation for carrying out more advanced work. The discipline science always needs the skills of exact, accurate and precise observation, attention and thoroughness of techniques, the logical arguments and interpretation of obtained data and meticulous estimation regarding the reliability of results.

Teachers are always anxious to stimulate learners' interest and participation thereby increasing the efficiency of their teaching. Also, a teacher is a creator of a learning situation. According to the nature of the content, the science teacher has to choose different methods of teaching. The learning experience that develops a skill need not develop knowledge and understanding. The effective teacher of science needs not only to know their subjects that are most likely to produce the desired results. Each method has its own strong and weak points. The method to adopt in teaching science is based on the following: (1) Nature of content, (2) Objectives of instruction, (3) Needs of the learner and their ability. The prevalent teaching methods do not consider and satisfy to the needs of all categories of children and do not help in the fulfilment of the aim and objectives of science. Its important to note that traditional teachers are concerned mainly with presentation skills leading to neglection of the student's participation and level of understanding. Traditional science teaching has focused on the direct transmission of truths. Development of the spirit of inquiry, the ability to solve problems and creativity in students, which are the main aims of science, are completely neglected in present-day science teaching. Teachers in the science classroom teach concepts without linking them. As a result, students of a discipline do not have an integrated vision of the branches of science. It was found that the student treats each branch of science separately. Here it can be recalled a new approach to teaching, concept mapping.

The "Plus two stage" forms the feeder stage for higher studies, both academic and professional. It is expected to learn various techniques of "how to learn" by the end of higher secondary. Here, a Chinese proverb can be recalled: "Instead of giving cooked fish, teach him how to cook fish". Which means training the students in how to learn would help in future they providing the facts.

In this context, concept mapping in PBL can act as a convenient teaching strategy. The investigator felt that the present instructional strategies are not adequate to help the students understand concepts in physics in Higher Secondary classes. This problem would be solved considerably by introducing concept mapping in PBL as a teaching strategy.

Numerous studies have been carried out separately to examine the efficacy of concept mapping strategy and problem-based learning approach on the achievement of primary, secondary, and higher secondary students. However, very few studies have investigated the integration of concept mapping strategies in PBL among higher secondary school students. Hence, the researcher planned to take up the study on the integration of concept mapping strategy in PBL and to find its effectiveness at the higher secondary level. This study will be beneficial to determine the effect of PBL and concept mapping techniques in assimilating the ability of problem-solving and self-regulated learning skills among the learners, which ultimately enhances their academic performance.

Statement of the Problem

The problem selected for investigation stemmed from the insight that Problem-Based Learning can be innovated further, making it a more promising educational approach. Various challenges faced by various teaching strategies in science education motivate the researcher to find an innovation. The researcher, from personal experience and after review of related literature, found that science teaching has gone through evolution and still needs to do research on reforming science teaching to stay relevant and effective. As part of this, the researcher attempts to study the effect of the PBL approach (using the KWHLAQ strategy in the problem-solving process) interlaced with the Concept Mapping Strategy. The present study is an effort to research experimentally the Effect of 'Concept Mapping' strategy in 'Problem-Based Learning' approach in Physics at the Higher Secondary Level. The study has been entitled as "EFFECT OF CONCEPT MAPPING STRATEGY IN PROBLEM-BASED LEARNING ON ACHIEVEMENT AND ATTITUDE TOWARDS PHYSICS AMONG HIGHER SECONDARY SCHOOL STUDENTS". This study gives a chance to find whether this innovation can be adopted to solve challenges faced by various other educational approaches of the same kind in science education.

Operational Definitions of Key Terms

The key terms which are defined operationally for the study are as follows:

Effect

The term "effect" refers to the measurable difference in students' achievement in Physics and their attitude towards Physics that can be ascribed to the implementation of the Concept Mapping Strategy within a Problem-Based Learning (PBL) environment, as compared to students who do not receive this strategy.

Problem-based Learning

Problem-based learning (PBL) is a learner-centered pedagogy wherein the learners are given an ill-structured problem from a real-life scenario. Students actively work in groups and apply John Barell's KWHLAQ strategy in the process of problem solving with the instructor (known as the tutor in PBL) as a facilitator

Concept Mapping Strategy

Concept mapping is a technique of presenting the information in a hierarchy where concepts, propositions, generalizations, etc., are linked by words in a semantic unit. They provide visual map presentation some of the pathways which a learner takes to connect the meaning of various concepts in a proposition. The student draws the concept maps during the teaching and learning process under the guidance of a teacher. The teacher draws the concept maps with the ideas of students and teaches them using a variety of methods.

Concept Mapping in PBL

In the context of Problem-Based Learning (PBL) using the KWHLAQ strategy, it is a graphic model that illustrates knowledge constructed by students in an organised manner. It encompasses the steps of organizing and making visible links between concepts around the stages of the KWHLAQ framework, which identify what is known, determine what has to be learnt (Want to know), outline strategies for how one finds the answers, records learnt information (Learned), evaluates how to apply the knowledge, and generates questions that extend the problem-solving process further.

Achievement in Physics

Achievement in Physics refers to the marks secured by the learners in the achievement test in physics constructed by the investigator.

Attitude towards Physics

Attitude is the mindset of individuals towards an object, event, idea or a person. In the present study, attitude towards physics can be defined as the mental disposition of a person towards Physics as a subject. An attitude scale consisting of sixty items under the following five factors: 1. Enthusiasm towards physics, 2.physics learning, 3. physics as a process, 4. physics teacher, 5. Physics as a future vocation was used to measure the attitude towards physics

Higher Secondary School Students

In the present study, "Higher secondary school students" refers to the students in science stream of class XI of Government Aided Higher Secondary Schools recognized by the Government of Kerala for imparting instruction to students of standards XI & XII.

Objectives of the Study

The main objectives of the study are,

1 To find out the effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning/Problem-Based Learning without Concept Mapping Strategy) on achievement in Physics of Higher Secondary School students.

2 To find out the effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning/Problem-Based Learning without Concept Mapping Strategy) on attitude towards Physics among Higher Secondary School students.

3 To study the main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and Logical Mathematical Intelligence on Achievement in Physics for the total sample.

4 To study the main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning /Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on Attitude towards Physics for the total sample.

Hypotheses

The hypotheses formulated for the study are:

1. There will not be any significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) with nonverbal intelligence and logical mathematical intelligence as covariates on achievement in Physics among higher secondary school students.

2. There will not be any significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) with nonverbal intelligence and logical mathematical intelligence as covariates on attitude towards Physics among higher secondary school students.

3. There will not be any significant main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on achievement in Physics for the total sample.

4. There will not be any significant main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on attitude towards Physics for the total sample.

Methodology in Brief

An experimental method is used for the present study. The design selected was the quasi-experimental pretest-posttest, comparison group design (Campbell & Stanley, 1963). The study is to be conducted on a final sample of 100 students of standard XI, and each division consists of 50 students among which one of the divisions is considered to be the experimental group and the other division as comparison group. A comparison has to be done between experimental and comparison groups, consisting of standard XI students, based on non-verbal intelligence test scores, logical mathematical intelligence test and pretest scores.

Population

The population for the study is Class XI students at Higher Secondary level who are studying in Government Aided Higher Secondary Schools of the State of Kerala, India.

Sample

Convenience Sampling is used to select 100 students of class XI, Higher Secondary level, who are studying in Kerala Govt. Aided Higher Secondary Schools of the State of Kerala, India. Out of which 50 students are included in the comparison group, and the other 50 students are included in the experimental group. "Convenience Sampling refers to one of the non-probability sampling methods in which the researcher selects participants based on ease of access and availability for the researcher" (Sedgwick, 2013)

Design of the Study

The details regarding design of the study are given in Table 1.

Table 1

Design of the Study

Stage	Experimental Group	Comparison Group
Pre-test	• Standard Progressive Matrices (non-verbal intelligence) • Logical- Mathematical Intelligence Test • Achievement Test in Physics • Physics Attitude Scale	• Standard Progressive Matrices (non-verbal intelligence) • Logical- Mathematical Intelligence Test • Achievement Test in Physics • Physics Attitude Scale
Treatment	• Teaching with Concept Mapping Strategy in Problem-Based Learning	• Teaching without Concept Mapping Strategy in Problem-Based Learning
Post-test	• Achievement Test in Physics • Physics Attitude Scale	• Achievement Test in Physics • Physics Attitude Scale

Variables

Independent Variables

The independent variables can be defined as the conditions or characteristics that the researcher manipulates or controls in his or her attempt to find out their relationship to the observed phenomena. Here, in this study, instructional strategy (Concept mapping strategy in Problem-Based Learning/Problem-Based Learning without Concept mapping strategy) was treated as an independent variable.

Dependent Variables

The dependent variables can be defined as the conditions or characteristics that may appear, disappear or varies as the researcher introduces, maintains or changes the independent variables. Also, the dependent variable is the outcome upon which the researcher compare the independent variable in an experiment. Here, in this study, achievement and attitude towards Physics are the dependent variables

Controlled Variables

In this study, the controlled variables are Non-Verbal Intelligence and Logical Mathematical Intelligence.

Tools and Materials Used for the Study

To gather necessary data, the investigator employed various tools. For the purpose of collecting required data, following six tools were employed:

(1) Nonverbal intelligence test (Standard Progressive Matrices)

(2) Logical Mathematical Intelligence Test.

(3) Lesson transcripts based on the concept mapping strategy in problem-based learning.

(4) Lesson transcripts based on problem-based learning without Concept Mapping strategy.

(5) Achievement Test in Physics

(6) Physics Attitude Scale

Statistical Techniques Used

The pre-test and post-test answer sheets collected from the students of both the experimental group and comparison group were assessed and scored according to the guidelines and scoring keys of each test. The scores thus obtained were tabulated, and the gain in scores was computed. The gain scores were treated as raw scores for the purpose of further statistical analysis. The following major statistical techniques were employed to analyse the data collected with the view to testing the hypotheses.

t-test

A t-test is a statistical test employed for comparing the means of two groups under consideration and determine if there is a statistically significant difference between them.

Analysis of Covariance (ANCOVA)

ANCOVA is a statistical technique to compare sets of data containing one or more means by controlling the effects of one or more covariates (In this study, non-verbal intelligence and logical mathematical intelligence)**.** This technique is useful for adjustment of dependent variable (achievement in physics or attitude towards physics in this case) for linear effects of covariates to obtain a clear understanding of the effectiveness of the instructional strategy.

Two-Way Analysis of Variance (Two-Way ANOVA)

Two-way Analysis of Variance is employed to compare the effect of two independent variables (instructional strategy and logical-mathematical intelligence in this case) on a dependent variable (achievement in Physics and attitude towards physics in this case). Also, this technique tests for interaction effects that indicate whether the effect of one independent variable on the dependent variable changes across levels of the other independent variables.

Scheffé's Post Hoc Test

The Scheffé test is a post-hoc test employed for analysis of variance (ANOVA) to find out which specific group means vary significantly from one another after an overall significant difference has been found.

These techniques will help in analysing whether the instructional strategies have a significant impact on achievement in Physics and attitude towards Physics, taking into account their levels of nonverbal and logical-mathematical intelligence.

Scope and Delimitations of the Study

The major aim of the investigation is to study the effect of Concept Mapping Strategy in Problem-Based Learning on achievement and attitude towards physics, to study the main effects and interaction effects of instructional strategy as well as logical mathematical intelligence on Achievement and Attitude towards Physics for the total sample. It is expected that the study would contribute some highlights towards Problem-Based Learning. An understanding of this approach will help teachers identify the conceptual framework of the unit they are teaching. Problem-Based Learning is suitable for teaching concepts, generalisations and principles. The study would help the physics teachers to understand the effect of concept mapping strategy in problem-based learning, problem-based learning without concept mapping strategy and the necessity of application of new techniques in the teaching of physics. It is expected that the findings of this study will advantage curriculum planners and those who are connected with the educational field. In short, using this approach provides a new meaning to education, as well as to the methods of teaching, learning and assessment of learning.

Delimitations are the boundaries and limitations that a researcher intentionally sets for the study. This study is delimited to only one school, and the sample was reduced to students of two divisions of std XI, each having 50 students. The investigator hasn’t included all concepts in physics due to the time limit. Only 20 lessons from 2 chapters of class 11 physics were considered for the study. Despite these limitations, the investigator claims that this study was conducted on proper guidelines and highest possible degree of objectivity, fairness and precision was achieved.

Organisation of the Report

Chapter I

This chapter was intended to throw a flash upon the nature of science, importance of science education, Problem Based Learning, Concept Mapping, Integration of Concept Mapping with PBL, need and significance of the study, statement of the problem, definition of key terms, objectives of the study, hypotheses, scope and limitations of the study.

Chapter II

A review of related literature and studies in the area of interest is conducted and recorded.

Chapter III

A detailed explanation of methodology of the research, preparation of the tools employed, sample selected for the study, procedure selected in the experiment and statistical techniques adopted for analysis.

Chapter IV

This chapter gives details of the statistical analysis and interpretation of the data collected.

Chapter V

This chapter gives a summary of procedures adopted and also attempts to examine the tenability of the research hypotheses, followed by conclusions and suggestions made for implementation and recommendations for further studies.

Chapter VI

This chapter gives the educational implications of this research study, along with recommendations for further research in the area under consideration.

Chapter 2

REVIEW OF RELATED LITERATURE

- ***Review of Related Theories***
- ***Review of Related Studies***
- ***Summary of Theoretical Claims***

The concept of PBL arises out of the necessity of eliminating rote memorisation, passive learning, theoretical knowledge with no practice, lack of creativity and skills, etc., among the current generation learners (Barrows, 2000). The PBL approach highlights the distinction between being "book-smart" and adopting a more holistic, practical approach that combines knowledge. PBL strategy can be regarded as a powerful shift from outdated ways of teaching, which are more often lecture-based. It has been used for 50 years, and it appears to be the most powerful constructivist pedagogical structure. Various studies have shown that PBL is effective in improving learner skills as well as applying them in problematic situations, which require problem-solving abilities. The primary aim of PBL is not learning for knowledge but learning for capability (Gallagher, 1997).

Concept mapping acts as an extremely useful tool both as a teaching and learning strategy and facilitates meaningful learning (Novak & Gowin, 1972). Concept maps help to evaluate the organisation of learning, the cognitive structure (Novak, 1984). Various research indicates that concept mapping is productive as a learning strategy that results in learning in children (Roth & Roychoudhury, 1993; Stice & Alvarez, 1987) and adult learners (McClure & Bello, 1999; Novak & Gowin, 1984) in a variety of subject domains. Concept maps are highly effective in assessing the organisation of the learning process, development of cognitive structure and comprehension of educational concepts in a particular subject matter (Novak, 1984).

By implementing Concept Mapping in the PBL process, students have to visualise their prior knowledge in the form of a concept map, which helps them to separate what is already known from what needs to be researched to better understand the problem and its underlying mechanisms (Johnstone & Otis, 2006). The main purpose why Concept Mapping strategy is considered to be advantageous for the Problem Based learning process is that it promotes the activation and elaboration of prior knowledge and makes students spend more time.

The researcher is interested in discussing the theoretical foundations and related studies of 'Problem-Based Learning', 'Concept Mapping' and 'Integration of Concept Mapping with PBL'. The study of related literature encompasses the systematic identification, along with analysis of documents comprising information related to the research problem. It enables us to understand the different aspects, development and scope of the area under research. For valuable study in any selected field of knowledge, the researchers require necessary familiarity with the research studies which has already been carried out in the area of interest. The researcher needs to obtain up-to-date information about what has been thought and done in the area of knowledge under concern. It avoids the repetition of what has been already done and offers useful hypotheses and helpful suggestions for significant further investigation. According to Best (1978), "It is a valuable guide to defining the problem, recognising the significance, suggesting, promising data gathering devices, appropriate study and source of data". The review of related literature provides the researcher with a thorough understanding of research methodology, which refers to the way in which the study has to be conducted. It benefits the researcher to identify and employ the tools and instruments which had been already proved to be useful in the previous studies. Also, it helps to review the recommendations of previous researchers listed in their studies for further research.

Review of Related Theories

Theoretical Aspects of Problem-Based Learning

Problem-based Learning Approach- Origin

In fact, we can say that the history of PBL starts as early as the rise of human beings, where they had to find new solutions for new challenges in their surroundings. The current concept of PBL has its origins in the constructivist theory of learning proposed by Jean Piaget (1972) and social development theory put forward by Vygotsky (1978). Problem-Based Learning can be said to have emerged in education during the 1960s at McMaster University, situated in Hamilton, Canada, where the biomedical students showed poor performance in academics as they were more focused on rote memorisation of biomedical concepts. It is often regarded as McMaster model of PBL and due to its acceptance, every year, a large number of schools started shifting their learning strategies to PBL which resulted in its extensions towards various disciplines like natural science, social science, mathematics, architecture etc. (Azer, 2001; Baker, 2000; Camp, 1996; Pijl-Zieber, 2006; Tan, 2003). The classic McMaster PBL approach has the components as follows: 1. Development of learning objectives concerning the provided ill-structured problem. 2. Identification of necessary educational information and resources. Also, seeking and synthesising (if needed) of information should be done by students before the next tutorial. 3. In the next tutorial, students have to bring the resources and information for discussion among peer groups. 4. The teacher will have a role as facilitator throughout the PBL process. 5. Self/peer/tutor-based assessment has to take place at the end. The McMaster model of PBL influenced the PBL approach in various institutions like Maastricht University, where the PBL approach was introduced during this period (Boud & Feletti, 1997). The credit of later advancement in PBL goes to Howard Barrows, who was a physician and neurologist as well (Stefaniak, 2016; Knoll, 1992). He did PBL experiments on medical students to solve their difficulty in applying basic knowledge while diagnosing a patient. Barrows found out that Problem-Based Learning (PBL) has a positive effect in improving student achievement and learning skills. In 2019, Noordegraaf-Elens and others explained how the PBL model by Barrows has its roots in the underlying information theory of psychology, which describes skills to be independent of context.. But several studies by scientists like Servant Miklos (2019), Ohlsson (2012), substantiate the fact that PBL is context-bound and cannot be considered as "generalised skills".

"One can explain the historical journey of PBL was that it was not a smooth path of development. Rather, it was a patchwork of borrowed innovations and diffuse understandings of various education philosophers set in a time where change and reform were in the air." (Servant- Miklos et al., 2019).

Later, numerous research studies, for example, the research done by Savery and Duffy since 1995, started taking place on the effectiveness of PBL. Various researchers had various views on PBL, as they are clear from the definitions put forward by each of them. The Problem-Based Learning strategy was then started to be used by some medical schools in America in the 1970s. In the 1980s, a report titled "Report of the Panel on the General Professional Education of the Physician and College Preparation for Medicine" was published, which gave widespread recognition to PBL in the United States (Muller, 1984). A curriculum-based introduction of PBL was done in the science curriculum of Memorial University of Newfoundland (Goodnough, 2005). It is the recent breakthroughs in interdisciplinary research which led PBL to spread to various fields other than the medical area (Tan, 2003). Now, several studies have proved the effectiveness of the PBL strategy in better conceptual understanding and problem-solving abilities. (Guo & Yew, 2016; Kadir et al., 2016; Thakur et al., 2021)

Problem-Based Learning – Concept and Meaning

Problem-based learning (PBL) can be considered as a student-centred pedagogy in which the students actively learn about a subject through the experience of solving open-ended problems (Savery, 1995). In a PBL environment, a learner, in the process of learning, comes across an ill-structured problem; this problem acts as a focus or stimulus to apply problem-solving abilities/skills (Barrows, 1996; Torp & Sage, 2002; Hmelo-Silver, 2004). In the process, the learner may have to deal with information and mechanisms needed to solve the problem. It involves the students to identify and dust off their prior knowledge and skills and apply them to solve ill ill-structured problem in a PBL environment. It is in this situation; contextualization of learning takes place (Sangestani & Khatiban, 2013). In short, we can say, the students are provided with a situation to conduct research, integrate the theoretical knowledge they have as well and apply it to get a solution for the given problem (Savery, 2006). In PBL, a relevant problem is introduced as a start, and thereby it follows with an investigation of the solution, resulting in progressive learning. However, the effectiveness of PBL mainly depends on student engagement, the PBL environment created by the teacher and the suitability of the provided ill-structured problem.

Problem-based learning can be used as an effective strategy in most teaching methods, but adapts well in multidisciplinary and interdisciplinary teaching and learning situations (Erdogan, 2015; Tan, 2003). This problem-based approach focuses on self-directed learning methods that are supported by teacher-guided activities. Students are exhorted to analyse the given problems, find appropriate materials or resources, utilise ICT tools and develop the skills of lifelong learning and independent study to come up with the best solution (Moallem et al., 2019). Also, students in a PBL environment take the responsibility for their learning by themselves (Kadir et al., 2016). The main feature of PBL is in its nature of mutual collaboration and group work, as well as in personal reflection, as one of its key aims is to cultivate the skill of independent lifelong learning. By working in groups, students will be able to recognise what they already know from previous learning experiences, what they require to know further, and how to access new information as well as where to access that will directly lead to the solution of the problem under consideration. In PBL environment, the role of the tutor is to enable learning by assisting, guiding, and monitoring the learning process in a careful manner. Tutor is vested with the responsibility of building learners' self-confidence to accept the problem, and facilitate the students towards finding a solution for it by guiding them. It is clear that Problem-Based Learning guides and engages students in acquiring knowledge while also inviting and motivating the students to create solutions to relevant problems. Compared to traditional instructional methods (viz., Teacher-based learning, subject-based learning, etc.), Problem-Based Learning, however, takes a more holistic approach. PBL change the focus to student-centred learning, which is more individualised and self-directed study. In PBL, students actively participate in the form of groups to analyse the problem, critically think, share ideas, generate hypotheses, and finally suggest solutions. By considering real-world problem solving, PBL helps students develop practical skills that are applicable beyond the classroom. Problem-Based Learning happens in an environment of small groups which analyse the given real-life situation/problem in a collaborative manner, following the concept of Social Learning Theory that learning occurs in a social context. PBL also account for observation learning as the learner is in a social environment. Obviously, in PBL, the learner is not passive; instead, they actively engage. Also, PBL is useful in cognitive development by providing them with opportunities to apply and strengthen the variety of intellectual abilities they possess.

Underlying Educational Concepts and Theories of Problem-Based Learning

Constructivist Learning Theory. PBL is based on Constructivist Learning Theory, which emphasises the construction of knowledge by the learners themselves. In Problem-Based Learning, the learners get engaged in real-life problems where they have to analyse and find solutions, thereby constructing knowledge by themselves. Through PBL, students are developing skills of critical analysis, interconnecting new and prior knowledge, Problem solving, etc, which are all by the required outcomes anticipated by Constructivist Learning Theory. Both PBL and Constructivist Learning Theory focus on active engagement of students rather than passively perceiving knowledge within a direct process of knowledge transmission. Also, in PBL as well as Constructivist Learning Theory, consider the instructor as a facilitator, not a teacher and the students are essentially involved in learning by sharing knowledge between them.

Situated Cognition Theory. The studies conducted by Miller and Gildea on vocabulary teaching show how the assumption- 'knowing and doing can be separated', leads to a new teaching method which ignores how a situation's structure influences cognition. Their work was comparing the vocabulary of students which they learned from the dictionary with the vocabulary they learned from their social environment. Situation Cognition can be regarded as a theory that says that learning happens only from doing by arguing that all knowledge acquired by a student is situated in activity bounded to social, cultural and physical contexts. It explores the idea that the concepts are both situated and developed through activity. This theory focuses on perception-action instead of memory-retrieval. Both PBL and Situated Cognition Theory suggest a model of knowledge acquisition which requires the act of thinking through activities rather than the storage and recalling of conceptual knowledge. Problem Solving through activities (as said by Situated Cognition Theory) done by he/she in connection with his/her environment stands distinct from the idea of learning by processing inside heads, to which many teaching practices focus.

Bandura's Social Learning Theory. According to Bandura's Social Learning Theory (1977):

i) Learning can be considered a cognitive process that takes place in a social context
ii) Learning can occur by observing a behaviour and the consequences of the behaviour
iii) Learning involves observation, extraction of information from those observations, and making observations about the performance of behaviour
iv) Reinforcement plays a role in learning, but is not entirely responsible for learning
v) The learner is not a passive recipient of information. Cognition, environment, and behaviour all mutually influence each other

Barell's KWHLAQ Strategy

Barell's KWHLAQ strategy was derived from good scientific observation processes. This strategy strongly fosters problem posing and inquiry processes. It gives stress on the fact that all teachers should have an idea about what and how to study. Barell designed the KWHLAQ strategy from Olge's (1986) K-W-L method. The K-W-L technique was designed to engage students in thinking about prior knowledge and the purposes for reading (Barell, 2007).

Barell's strategy expanded the limited application of the KWL technique to long-term curricular units of instruction. In the KWHLAQ strategy, the letters represent the following questions:

K- What do we think we '**know**' about the subject? (Barell, 2007)

W- What do we '**Want/Need**' to find out about it? (Barell, 2007)

H- '**How**' are we going to find it out? How will weorganise ourselves to investigate the use of time, access to resources, and planning for sharing findings? (Barell, 2007)

L- What do we expect to '**Learn**'? What have we learned? (Barell, 2007)

A- How will we '**Apply'** what we have learned to other subjects, to our personal lives? to our next projects? (Barell, 2007)

Q- What new '**Questions**' do we have following our inquiry? (Barell, 2007)

The KWHLAQ strategy holds many advantages. The following are the main advantages of KWHLAQ:

1. This strategy taps into what students think they already know, thereby identifying prior knowledge and some misconceptions about important concepts (Barell, 2007).
2. Changes traditional control patterns in the classroom. Students get the opportunity to ask important questions of their own (Goodland, 1984). Students' questions help them to lead an inquiry.

3. Students get opportunities to identify what is important to them, to relate the subject matter to their curiosities, their puzzlements, and their gaps in knowledge.
4. This strategy provides the teachers an opportunity to help students analyse complex issues by asking, “What do we want and need to know about this situation?” (Barell, 2007). This promotes students’ ability to analyse complex problems.
5. The question ‘What do we need to ask /determine about this situation?’ empowers the students to think and act more on their own (Barell, 2007).
6. This strategy puts the students in touch with multiple resources (such as the internet, adults outside of school, and other students) through the question “how do we find answers?’. It develops students’ efficacy, ownership, and self-direction. Moreover, over students feel the power of responsibility for their learning.(Barell, 2007)

Problem-based Learning- Process

In a PBL environment, students are involved in the learning process related to the solution of a provided ill-structured problem. Students become active in small groups and work in the context of given problem scenario. Here, the tutor plays the role of a facilitator who actively guides the students towards obtaining the solution. In this process, students develop problem-solving ability and critical thinking skills, and also take responsibility for their learning process. Different PBL models propose different PBL processes. A model of problem-based learning was developed by Barrows (1996) based on the McMaster model of PBL, which was applied in medical education. Barrow's explanation of PBL is simple, with the central idea of student-centred learning and can be considered authentic to a great extent.

According to Barrows (1986), Hmelo-silver (2004), Schimdt et al. (2009), PBL can be regarded as a recurring process comprising 3 phases, viz., i) Initial Problem Analysis, ii) Self-directed individual learning, iii) Subsequent reporting phase. Also, there are several other researchers like Tamblyn, Schmidt, Jonassen and Wood, etc. who studied PBL more or less like how Barrows did.

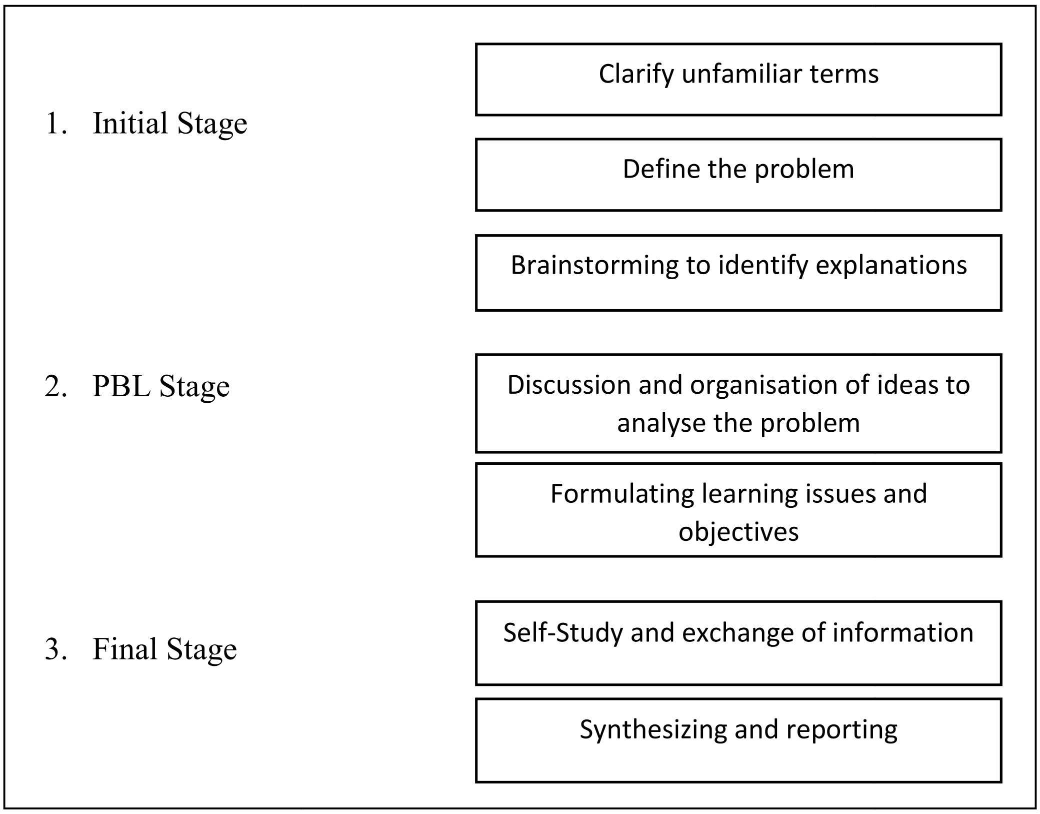
Classic McMaster PBL. The founders of PBL at McMaster University explained it as a kind of learning process that takes place during the active participation towards obtaining the solution of a given ill-structured problem. The problem is met first in the course of learning and acts as a focus or stimulus for the application of problem solving abilities/skills, as well as for the search for or study of information or knowledge which is needed to understand the mechanisms responsible for the problem and how it might be resolved (Barrows & Tamblyn, 1980). Active student-centred learning in a self-regulated manner is the core idea of the McMaster model of PBL, with the following steps of the tutorial process:

1. Identifying the ill-structured problem under consideration
2. Exploring prior knowledge and skills by the students, which ultimately aids them in solving the problem
3. Generating hypotheses and mechanisms towards the solution of the problem through self-study and research
4. Identifying the objectives as well as the issues in the learning process
5. Reconsideration of their approach towards the problem and application of new knowledge to the problem
6. Self/peer/tutor assessment followed by self-reflection

Maastricht Model of PBL (Wood, 2003). Maastricht University is well known for its steps towards contributing to the advancement of the PBL approach, like internationalisation of PBL. PBL innovations brought by Maastricht University, such as the step method, skills lab, etc., are remarkable. The Maastricht model of PBL is often called as Seven Jump Model (Maastricht PBL model), in which the PBL process is divided into 3 stages (Masek & Yamin, 2010).

Figure 1

Maastricht Model of PBL



In the process, students are randomly split into several small groups, each provided with an ill-structured problem (Hmelo-Silver, 2004). When the tutor is assigning the problem, it is important to clarify the meaning of all terms related to the problem, which helps the students to define the problem in a better way in the next step. It is the peer group discussion which leads them to define the problem. In the next stage, i.e., PBL stage, firstly, the students try to interlink the problem with their previous knowledge and thereby create a hypothesis, called a brainstorming session (Wee, 2004). The hypotheses of all the group members are put together with no analysis (Hmelo-Silver, 2004). It is in the very next step; all the members of the group analyse the hypotheses and explanations are examined in a bulk and rigorous manner. The group members then come to know the knowledge gaps, contradictions and ambiguities among themselves and help them to formulate learning issues and learning objectives (Schmidt, 1993; Barrows and Tamblyn, 1980; Hmelo-Silver, 2004). Questions like "what do they know?", "What they do not know" and "what they need to know" will enable the students to understand learning issues and the setting of learning objectives. Then comes the 'self-study' step in which students master the knowledge which is relevant in the context of an ill-structured problem, i.e., the related literature (Schmidt, 1983). Students exchange the information and reach a commonly accepted hypothesis (Schmidt, 1983; Wee, 2004). When the students, in the final step, synthesise and report the solution, the tutor evaluates/assesses the students with immediate feedback (Barrows & Tamblyn, 1980; Woods, 2000; Kolmos & Holgaard, 2007). In some cases, peer group assessment is also employed (Kolmos et al., 2007). It is important to note that, throughout the PBL cycle, the teacher has a role as facilitator to guide the learners (Hmelo-Silver, 2004)

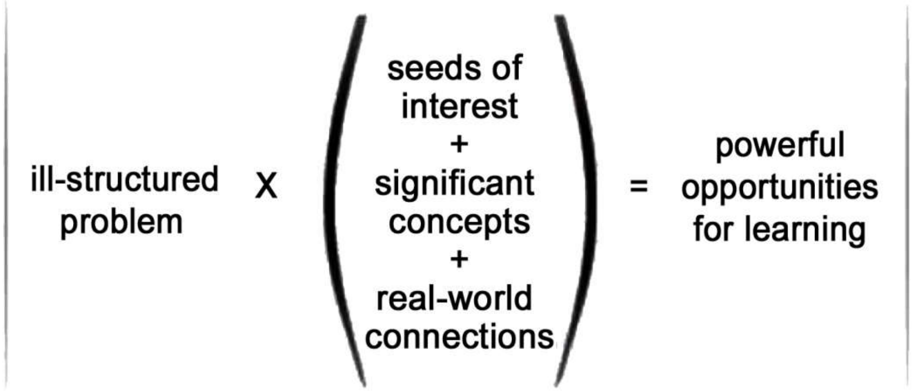
Torp and Sage's Explanation of the PBL Process. Torp and Sage (2002) say that Problem-Based Learning is mainly comprised of two complementary processes. They are: 1. Curriculum Organisation; 2. Instructional Strategy

Curriculum organisation is completely in the hands of learners. In a PBL environment, students understand, define and analyse a provided problem in which students do a self-study, critical thinking and research on a self-constructed curriculum around the given problem. At the same time, instructional strategy is completely in the hands of the tutor (or facilitator) who guides and facilitates the students towards the solution of the problem.

Torp and Sage (2006) review the PBL process in a simple way as shown below:

Figure 2

PBL Process Adapted from Torp and Sage (2006)



Tan (2002): Problem-Based Learning Process Scheme. Tan (2002) has put forward a typical 5-step Problem-Based Learning process scheme as follows:

1. ***Encountering the Problem***. In a PBL environment, students are first met with a relevant problem provided by the tutor to be solved in a self-regulated learning manner, by the objectives of PBL.

2. ***Learning Issues and Analysis of the Problem.*** Students are required to be involved in brainstorming and link the problem with their previous knowledge, think critically, and find a way to solve the problem. These PBL activities help the students to identify their learning issues and formulate learning objectives in a self-directed manner.

3. ***Reporting the Information, they Discovered.*** Each student comes up with their hypothesis/information after conducting self-study and research, and they report it in the group for the purpose of sharing it with others and arriving at a common hypothesis.

4. ***Presentation and Reflection of Solution***. The shared hypotheses are subjected to thorough analysis within the group and thus arrive at a common

hypothesis, which forms the solution to the given problem. The solution is then demonstrated/presented to the tutor. Tutor, acting as a facilitator throughout the PBL process, clarifies the doubts and misconceptions (if any) around the problem and its newly found solution. This leads the students to reflect upon their knowledge gaps and level of understanding.

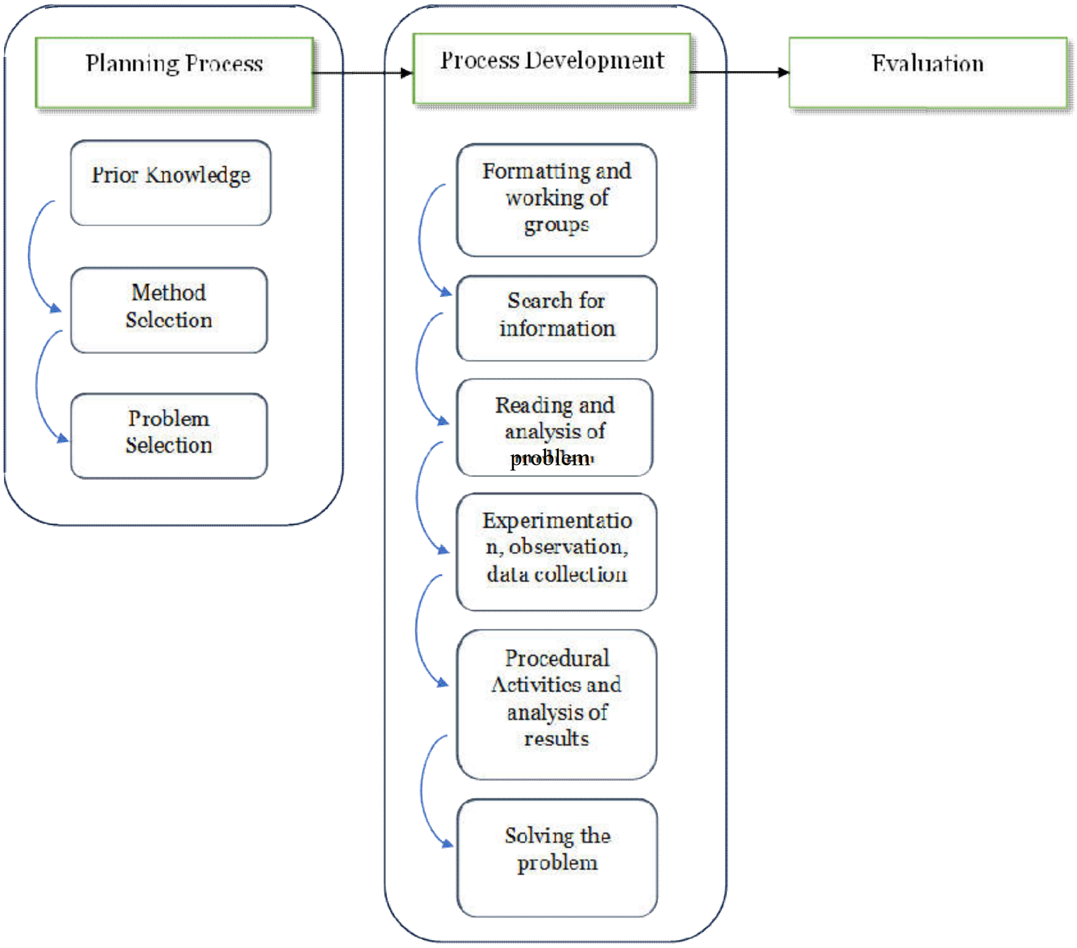
5. ***Integration, Overview, and Evaluation***. Tan considers integration, overview, and evaluation to be the final stage in the PBL process in which the students integrate the knowledge from various disciplines as well as the knowledge they synthesised during the process with the solution of the given problem in the PBL approach. This leads to the creation of knowledge upon which students reflect and evaluate themselves. Tutor has a great role in this stage in facilitating students to summarise and integrate important concepts and principles

PBL Process: Based upon Barrow Elaborated by Vargas-Rodriguez, et al., 2021. PBL is considered to be a process in which a small group of students work on a problem-based and find out related information as well as use their previous knowledge and experiences to solve it (Vargas-Rodriguez, et.al. 2021). Based on Barrows' methodology of PBL, Vargas-Rodriguez et al., explained PBL as a process of 3 fundamental stages:

1. Planning Phase
2. Process Development Phase
3. Evaluation Phase

Figure 3

Stages of Problem-based Learning process (Barrow and elaborated by Vargas-Rodriguez et al., 2021)



In the planning phase, the first step is taking prior knowledge of students into account, as it is on that foundation, students construct new learning appropriate for solving the PBL problem. The next step is to select the method, as the students need self-directed learning according to their competency. The selection of the problem is to be done in such a way that it is relevant, having a similarity to real-life situations. The problem should have a complex nature, but it should not be impossible so that the students can apply their problem solving abilities and critical thinking skills.

During development phase, tutor carry out grouping of students as the first step, in which each group containing four to seven members. Students are then expected to analyse the problem and understand its demand. In this step, the tutor has the role of facilitating them by clearing their ambiguities and being attentive in the group discussion among students. As a group, the students collectively work towards gathering information and resources which seem to help solve the problem. There are situations in a PBL environment where students have to check the validity of their arguments or hypotheses through an experiment in the context of the problem. Data is collected from experimentation to check its validity. Collected data and new knowledge are presented as a solution to the problem after thorough investigation, discussions and analysis within the group. The tutor may help the students if necessary, for processing new knowledge, experimental data, etc. The group leader of each group is supposed to present their solution to the given problem either in written, oral, or ICT means.

Evaluation phase, the final phase of the PBL process, can be done in several ways, like peer assessment (co-evaluation), self-assessment or tutor assessment.

Role of Teacher in PBL Process

The role of the teacher in fostering PBL among students is undeniably vital (Pea, 1993). In a PBL classroom environment, an 'unfamiliar observer' cannot see a teacher at the blackboard, but may find the teacher within the students' groups who facilitates them to learn, unlearn and relearn on their own. In a PBL classroom, the teacher is no more the centre of attention like a traditional classroom (Delisle, 1997). Instead of providing information like a traditional teacher, a PBL teacher facilitates the learner with the facilities required in the learning process and by developing appropriate learning thinking skills in learners. PBL with proper facilitation through tutors could offer a great opportunity to the students to restructure and reconstruct the nature of knowledge and learning to solve real-world problems or problematic scenarios (Ogbuanya & Akinduro, 2017; Landsberger, 2011). As time passes, as the learners start to become self-dependent in the learning process, the teacher gradually starts to withdraw the assistance which was being provided before. Hence, the main role of a teacher can be considered to act as a guide who guides the students through all stages of the PBL process, ensuring that necessary PBL skills are being developed in students all the way and at last the PBL goals are attained (Koschmann et al., 1994; Hmelo-Silver, 2006). PBL teachers can employ a variety of techniques such as open-ended and metacognitive questioning, externalising self-reflection by asking relevant questions, etc (Hmelo-Silver & Barrows, 2008).

Delisle (1997) wrote "How to Use Problem-Based Learning in the Classroom" in 1997, in which he says that a PBL teacher has the following three important roles: 1. PBL teacher as Curriculum Designer 2. PBL teacher as Guide 3. PBL teacher as Evaluator; According to Schimdt and Moust's (2000), the following are the main factors for a teacher to be an effective facilitator in a PBL classroom: 1. A solid knowledge base of the topic under consideration, 2. A positive attitude to get involved with students in a reliable way 3. A skill of expressing oneself in a language understood by students; According to Weizman et al. (2008), the following components are needed by teachers to apply the PBL method effectively: 1. Good understanding of the subject under consideration, conceptually and strongly with skills and abilities in applying knowledge to new situations. 2. Potential and capacity to reason out incomplete information. 3. Ability to take appropriate decisions as well as ask questions which are best for the class, as well as at the individual level.

Role of Students in the PBL Process

Students are divided into groups who follow the steps of the PBL strategy. Each of the group members has to participate in discussions, pay attention and respect the opinions of other members, and stimulate the discussion by asking questions. Students have to do research by themselves on the learning objectives and share the acquired information with the group members for analysis and synthesis of new opinions and conclusions. According to Torp and Sage (1998), students who are hooked by an intriguing, problematic situation seek needed information, pursue the investigation and actively learns through support from a coach and self-directed learning. In the problematic situation, students apply their knowledge, skills and habits of mind to meaningful and authentic activity (Torp & Sage, 1998).

Role of Problem in PBL Process

The problem acts as a beginning point for the process of learning (Boud, 1985). All PBL processes get started with a problem (Hung, 2016). The problem, to be provided for students, should be developed in a manner that it serves as a source of 'trigger' to motivate the students and cultivate interest. Also, the problem should not be so easy that it can be solved in just one step; instead, it should require more than a single step towards obtaining the solution, facilitating the student towards structuring a relevant definition out of the problem (Lasry, 2008) Students should deal with the problem with multiple solutions via multiple paths. In PBL literature, the problem should be authentic, real-life situation, complex and ill-structured (Dolmans & Snellen-Balendong, 1997; Torp & Sage, 1998). This will give the students a sense of ownership of the learning process. The ill-structured nature of the problem is comparable to the chaos and complexity of the outer world, which ultimately makes the students capable of finding possible solutions for real-life problems (Wilkerson & Gijselaers, 1996). It is clear that, PBL problem offers a situation (or say, it sets a learning environment) to apply, check and evaluate their different kinds of knowledge. The nature of the problem in PBL is contrary to the well-structured problems in textbooks, as the latter do not resonate with everyday situations (Lave, 1988; Roth & McGinn, 1997).

Advantages of Problem-based Learning Approach

Whatever discipline it may be, PBL affects students' achievement in a positive way (Barrows & Tamblyn, 1980; Engel, 1997). Pawson et al. (2006) had analysed various related literature of PBL to obtain a critical picture of PBL in various aspects such as its purpose, benefits, risks, etc. The following flowchart will help us to see the benefits, listed by him, of PBL for students and instructors:

Benefits of PBL for Student	Student centred approach
	Scope for greater understanding
	Better concept formation
	Skill development
	Enjoyable and fulfilling
Benefits of PBL for Teachers	Higher level of student comprehension
	Enhance class attendance
	Promotes interdisciplinary aspects in education
	Role as a facilitator
	Active engagement of students

The PBL strategy seems to enable learners for skill acquisition through content in the context of real-life situations (Tseng et al., 2008). Also, it substitutes the traditional way of learning through lectures with classroom discussions, facilitation by a mentor, assisted learning, etc, which motivates the students to actively learn more deeply (Weimer, 2009; Jones, 2006). As in a PBL environment, lessons are taught in an indirect manner, which motivates the learners to take initiative in their learning; this, as a result, makes the learning process more fascinating (Jones, 2006; Abdelkarim et al., 2018). A student learning in a PBL environment possesses their knowledge for a longer period and also retrieves it easily, whenever necessary, in new learning situations (Bates, 2014). As a problem-based learning technique requires prior knowledge of the students to solve ill-structured problems, the students will be constantly updating and revising their prior knowledge, which results in more stronger foundation of students in the fundamentals of different subjects (Weimer, 2009; Bates, 2014). For a given problem in a problem-based learning environment, students are required to think about it in various aspects, instead of blindly following the lectures in a direct, taught manner. Hence, students take initiative to think by themselves about how, where and why the aspect of problems got introduced, and it ultimately enhances their critical thinking skills (Duch et al., 2001; Bates, 2014; Carvalho, 2015). The application of suitable metacognitive and reasoning skills for finding the solution to the given problem is essential in the problem-based learning process. Hence, we can say that it develops problem-solving skills among learners (Duch et al., 2001; Carvalho, 2015). Group discussion is an important component of the problem-based learning process. This will result in improvement and development of interpersonal skills based on their collaboration and teamwork within the group as well as with other groups (Bates, 2014; Carvalho, 2015; Abdelkarim et al., 2018). Government of transferable skills can be considered as another important advantage of PBL why because the learners become capable of using the comparable skills they have already learnt while solving previous real-life related problems, to new problematic situations posed before them (Carvalho, 2015).

Oystila (2006) classified the advantages of PBL into 3 broad categories, viz.,

1. Learners' holistic self-development (Oystila, 2006)
2. PBL tutors learning at work (Oystila, 2006)
3. The opportunity to develop the curriculum and relationships through dialogue (Oystila, 2006).

Problem-based learning as a student-centred learning environment proves to provide freedom to individuals during the learning process (Leary, 2012). There are studies which report that problem-based learning technique enhances the students' academic achievement in constructing knowledge compared to traditional teaching methods, where just memorisation of facts directly given by the teacher is occurring and considered as learning (Akcay, 2009; 26 Goodnough, 2003; Polanco et al., 2004; Sungur et al., 2006). Considering PBL as a pedagogy seems to be very effective as it mainly focuses on the affective domain of learners such as their attitude towards the learning process, their motivation, synthesis of contextual and permanent knowledge and skill acquisition such as problem-solving skills, research skills (Kaufman & Mann, 1997; Sifoğlu, 2007; Tugwell, 2020).

Theoretical Aspects of Concept Mapping

Concept Map can be regarded as a visual display which represents the relationship between concepts and ideas. They are hierarchical with one main idea and several subtopics. Concept maps consist of nodes, representing concepts, connected by lines/arrows, indicating the relation between concepts. Concept Maps are useful in a learning environment because they help students to visualise, organise, relate and analyse information easily. Personalised concept maps constructed by students help them in an easy as well as deeper understanding of the topic in a shorter amount of time. Concept maps give way for students to active learning by requiring students to be actively involved in making them based on their level of understanding.

Concept Mapping-Origin

Well-known science educator Joseph D. Novak and his colleagues did research on the role of previous knowledge in the learning process and distinguishing rote learning and meaningful learning (Novak, 1984; Gowin &

Johansen, 1983). It was found out by Novak that only a small number of students in formal education have had any formal guidance in knowing ‘how to learn. He states that the process of learning consists of assimilation of new concepts and creation of a mental framework by arranging concepts in a hierarchical manner (superordinate concepts arranged in the higher part and subordinate concepts in the bottom area of the map). Novak’s research led him to find new metacognitive strategies in assisting meaningful learning (Novak et al., 1983; Resnick, 1983; Gibbs, 1981; Flavel, 1976; Biggs, 1988; Thomas et al., 2007). For example, Concept Mapping strategy is a metacognitive strategy for assisting meaningful learning, which was formulated by Joseph D. Novak in a research program at Cornell University in the year 1972 (Novak, 1984; Gunstone, 1992). The cognitive psychology put forward by David Ausubel, which explains meaningful learning as a process of assimilation and accommodation of new concepts into already existing schemas of the learner, has influenced Novak’s work. Ausubel considered the mind to be a hierarchical organisation of information which acts as an anchor for information, comparable with an academic discipline. It is Ausubel’s idea of ‘hierarchical presentation of concepts’ which led to the origin of cognitive maps or concept maps (Ezeudu, 1995). Not only Ausubel’s work, but also various other information models, such as (see below), have an effect in evolvement of educational strategies resulting in the formulation of concept mapping strategy.

Underlying Educational Concepts and Theories

Concept Mapping as a Constructivist Approach. The key postulation of constructivism is that knowledge does not exist in an objective reality. It is actively constructed within the learners (Hendry & King, 1994). New knowledge is acquired through learning by integration with prior knowledge (Ausubel, 1968). Concept mapping – visual representation of knowledge structure, meaning and understanding in a graphical form (Novak & Gowin, 1988) – has its origin in theory of constructivist learning as well; which explains learning process as formulation of new knowledge using already existing similar and related pieces of prior knowledge and experiences in the cognitive structure of a learner (Chularut et al., 2004). Concept maps are created by arranging concepts in a hierarchical way, which represents the mental structure of a learner where he/she actively participate in mental activities such as reading, thinking, arranging, and relating the concepts to each other with connecting linkages to conclude. According to the division of constructivist ideologies into 3 categories by Moshman (1982), concept mapping aligns with exogenous constructivism, which focuses on the way through which a learner reconstructs their outside reality by building accurate mental representations such as concept maps, propositional networks and schemas (Moshman, 1982).

Ausubel's Subsumption Theory. Ausubel's Theory tells us how a learner acquires a large amount of information in a school setting. "The most important factor influencing the learner is what the learner already knows" – Ausubel (1968) Educational Psychology: A Cognitive View

According to him, "the predominant process in learning is subsumption, where the new concepts are related to relevant ideas in the existing cognitive structure of the learner". One of the main principles put forward is the principle of instruction. It is as follows: "Instructional materials should attempt to integrate new material with previously presented information through comparison and cross-referencing of new and old ideas". Concept maps can be, thus, regarded as one of the suitable instructional materials for learners by Ausubel's theory.

Piaget's Theory of Cognitive Development. Piaget's theory is mainly based on his 4 concepts, called Piagetian Concepts. They are,

i) Schema - a framework that systematises and interprets new information
ii) Adaptation - Learner's tendency to get familiar with a new schema using interaction, experimentation, etc.

iii) Assimilation - Process of integrating new information with already existing schemas.

iv) Accommodation- Process of restructuring of already existing schemas to accommodate new information

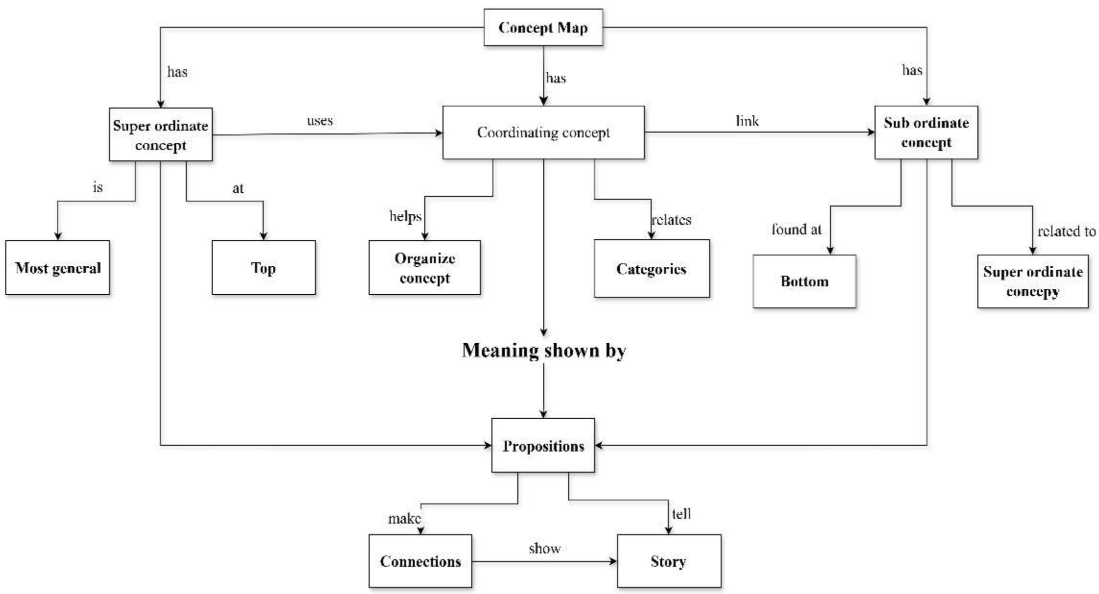
Concept Maps are based on Piaget's Schema Theory. Creating and interpreting concept maps allows the learner to construct as well as restructure schemas, along with linking new and old schemas. Both Concept Mapping Strategy and Piaget's theory are focused on the interconnected nature, modification and organisation of knowledge.

Concept Map – Structure

The following figure depicts the structure of the concept map.

Figure 4

Concept Map Structure



"Concept maps are two-dimensional, hierarchical, node-linked diagrams that depict verbal, conceptual, or declarative knowledge in visual or graphic forms" (Quinn et al., 2004; Horton et al., 1993)

"Concept map is a systematic, schematic and graphical tool that presents a set of concepts or ideas enclosed in a framework of prepositions" (Novak, 1984)

"Concept maps are the representations of the knowledge or information in the form of concepts or their interrelationship that human beings store in their cognitive structure" (Jonassen et al., 2006)

"Concept map is a pictorial representation of a domain that consists of concepts represented as nodes that are connected by arcs or links" (Crandell et al., 1996; Borough & Rye, 1997)

"Concept Mapping is a nonlinear, graphic representation of unstable domains, depicting major concept nodes and the interrelationships of those nodes. It is a learning strategy identified as having a significant impact on retention and retrieval of information, with continued processing of data over time" (Nelson, 2007).

"Concept mapping is a process or technique of representing concepts and their interrelationship in a two-dimensional structure, showing the concept in a topic/units in their aches and interconnections" (Olusola & Hammed, 2008).

The 6 terminologies of concept mapping:

1. Concept. A concept is a 'mental notion' of things or events obtained through the process of perceptual classification and discrimination. In concept maps, concepts are shown in isolated circles which have positions based on their classification as super concepts and sub concepts and examples. Different colours can be given for the attraction and recognition of concepts.

2. Nodes. Concept maps are a network of concepts, which consist of many nodes which represent concepts.

3. Links. They are labelled arrows that represent the relations between various concepts. Labels can be linking phrases. Links can be one-way, two-way, or non-directional.

4. Propositions. They are meaningful statements containing two or more concepts linked using linking phrases (Novak, 2007)

5. Cross Links. They are links between different concept domains, leading to the synthesis of related concepts, creative thinking, and new interpretations.

6. Hierarchy. Concept maps have their concepts arranged in descending order of importance to have a hierarchical nature. Super concepts (the most important concepts) are often placed at the top, and lower-order concepts are used to obtain a whole concept map. Super concept can also be placed in the central part with outward branches towards related concepts.

Concept maps include concepts, usually enclosed in circles or boxes of some type, and relationships between concepts or propositions, indicated by a connecting line between two concepts. Words on the line specify the relationship between the two concepts. We define a concept as a perceived regularity in events or objects, or records of events or objects, designated by a label. Propositions are statements about some object or event in the universe, either naturally occurring or constructed. Propositions contain two or more concepts connected with other words to form a meaningful statement. Sometimes these are called semantic units, or units of meaning

Another characteristic of concept maps is that the concepts are represented hierarchically, with the most inclusive, most general concepts at the top of the map and the more specific, less general concepts arranged hierarchically below. The hierarchical structure for a particular domain of knowledge also depends on the context in which that knowledge is being applied or considered. Therefore, it is best to construct concept maps concerning some particular question we seek to answer or some situation or event that we are trying to understand through the organisation of knowledge in the form of a concept map. Another important characteristic of concept maps is the inclusion of "cross-links." These are relationships (propositions) between concepts in different domains of the concept map. Cross-links help us to see how some domains of knowledge represented on the map are related to each other. In the creation of new knowledge, cross-links often represent creative leaps on the part of the knowledge producer. Two features of concept maps are important in the facilitation of creative thinking: the hierarchical structure that is represented in a good map and the ability to search for and characterise cross-links. A final features that may be added to concept maps are specific examples of events or objects that help to clarify the meaning of a given concept.

Concept Map- Purpose. “Concept map is purposeful and helps teachers to become more effective” (Begerkach & Smith, 1990; Hozetal, 1990). Concept maps harness the power of our vision to understand complex information “at a glance”. The primary function of the brain is to interpret incoming information to make meaning. It is easiest for the brain to make meaning when information is present in visual formats. This is why a picture is worth a thousand words. Concept maps can be used for a variety of purposes. Three general purposes of concept mapping are as follows: *1. Instructional tool; 2. Student learning tool; 3. Assessment tool.*

1. Concept Mapping as an Instructional Tool. To organise course content - By constructing a large concept map of all of the major terms and ideas of a course, the instructors can use such a framework to organise course content. This provides a way for the instructor to see connections between the course material and how to best present those connections to the students. To prepare specific lessons - Rather than mapping an entire course's content, an instructor may focus on the more specific task of mapping content from only one lecture to organise the particular lesson. To present material to students - An instructor may choose to teach course material through the use of concept maps to clearly show the students the connections between terms.

2. Concept Mapping as a Student Learning Tool. To learn course material, Students can use concept maps to take class notes. Students can use concept maps to organise class notes or course material. To integrate course content, Students can use concept maps to connect what they have learned in the course. To integrate material across different courses, students often fail to see the relationship between different classes that they have taken. Concept mapping can foster a student's understanding of how different courses relate if they map the prominent concepts from different courses that they have taken.

Individual and cooperative concept mapping - individual concept mapping has an individual-centred purpose where the learner self-reads and self-organises their knowledge structure, resulting in a self-realisation of understanding and measuring of their knowledge structure at a later stage. Cooperative concept mapping is more purposeful than individual type concept mapping, as in the former type, students work in groups to share knowledge and understanding, facilitating communication, eradication of misconceptions, research skills, internal assessment and evaluation skills.

3. Concept Mapping as Assessment. To evaluate student learning, Concept maps can be used to assess changes and growth in the students' conceptual understanding as a result of instruction received in the course. Learning can be evaluated before a course begins (to evaluate students' prior knowledge), during the semester (to evaluate changes in the students' knowledge), and/or at the end of the semester (to evaluate the students' knowledge after all course material has been covered). Concept maps can be used to evaluate changes in learning over time (formative assessment). Concept maps can be used to evaluate end-of-course knowledge (summative assessment).

To give student and instructor feedback - A concept map can provide feedback to the student so that s/he can check his/her understanding of the material to see if any connections are missing. A student's concept map can provide feedback to the instructor so that s/he can check to see if there are misconceptions represented in the maps and if there is a trend in those misconceptions. Such a trend may reflect an instructional area that needs further clarification.

When using concept maps for assessment purposes, it is important to realise that less experienced mappers will most likely produce lower quality maps than more experienced individuals. Therefore, a student may have a good understanding of the material, but that may not be reflected in the concept map because s/he is not entirely comfortable with the procedure of concept mapping. It is advisable to 23 integrate the practice of concept mapping in the course as an instructional and/or student learning tool when using concept map scores to count for course credit, so that there is a match between instruction and assessment.

Concept Map - Significance. Concept maps are meta-cognitive tools that allow the representation of knowledge structure in thematic fields and the disclosure of ‘secrets’ in the cognitive structure of students of all eyes. As a learning strategy, concept mapping stimulates learners’ commitment, interest and participation in formulating a visual representation of concepts, interlinking them to construct a web, which results in meaningful learning. Concept Maps are also advantageous as a teaching tool, as they facilitate the learners to establish a networks of concepts that gradually differentiate a central concept from various other related concepts in a structural, integrated and progressive manner, guiding the way of teaching learning process. Concept Mapping strategy enables us to function at the 'knowledge reorganisation level' facilitating the storage of knowledge in their long-term memories. Teaching methods based on Concept Mapping strategy provides the scope for proactive formative assessment and reinforce their didactic role. Thus, we can conclude that this instrument (Concept Mapping strategy) offers a new sense and meaning to the field of education, as well as to the concepts of teaching, learning and assessment of learning. In the phase of curriculum planning, concept maps have a huge scope, adoption of which can be immensely useful. They present the key concepts and principles to be transacted in a highly concise visual manner. As the concepts are hierarchically organised in concept maps, it enables effective and meaningful sequencing of instructional material by learners. Since the fundamental principle of meaningful learning is the meaningful construction of knowledge through integration of new knowledge with already existing knowledge of previous concepts and propositional frameworks. Learners in a meaningful learning process, proceed from more general and inclusive concepts to the more specific information which ultimately serves to encourage and enhance meaningful learning. Thus, in the phase of curriculum planning, it is necessary to develop a "macro map" which shows the major ideas which needs be taught in the whole course, or say whole curriculum, and then, more specific "micro maps" to show the concepts which needs to be transacted for a very specific segment of the instructional session. Utilising Concept Maps in curriculum planning or instruction on a selected topic helps to make the instruction "conceptually transparent" for students. In science learning, many students face difficulty in identifying and constructing concepts and propositional frameworks, leading them to see science learning as a blur of myriad facts or equations to be memorised. If concept maps are used in planning instruction and students are required to construct concept maps as they are learning, previously unsuccessful students can become successful in making sense out of science and acquiring a feeling of control over the subject matter (Bascones & Novak, 1985; Novak, 1991; Novak, 1998)

Moreover, concept mapping has great significance in developing social, moral and emotional aspects of students in the following way:

Social Skill. Construction of concept mapping involves the students in interaction and communication among peers. This can be considered as a socialisation process where social rules and relations are created.

Cooperation. Constructing concept maps involves a process of cooperation in which peer groups work together in a harmonious and side-by-side manner

Creativity. A concept map is created from deep-level diversity in group members create minds. It is hence clear that cognitively diverse work groups are superior to cognitively homogeneous teams about the prerequisites of innovation, like gathering, processing, and applying information in the map.

Open-mindedness. A learner shows increased brain activity by becoming more open to new ways of thinking, interpretation of experiences, and changes in previous thinking

Concept Map-construction. To learn how to construct a concept map, it is preferred to begin with a field of knowledge that is familiar to the learner who is constructing the map. As the structure of concept maps are reliant on on the context in which they are going to be used, it is recommended to pick out a segment of a text, a laboratory activity, or a particular problem or a question, according to the context, that the learner is expected to understand (often provided by the teacher in a classroom situation). Once the field of knowledge is selected, the following step is to recognize the key concepts that apply to the selected domain of knowledge. This leads to the creation of an initial framework which will help, in prior, to determine the hierarchical structure of the concept map which is being constructed. These key concepts could be listed down, and then from this list, a rank order should be attributed from the most general and most inclusive concept, for this particular problem or situation, to the most specific and least general concept. Even though this rank order may be only approximate resulting in changes in ranks at a later stage of construction, it helps to initiate the concept map construction process. The next step is to make an attempt in constructing a preliminary concept map. Students will start the construction process by placing key concepts in the top/centre and linking them to related sub-concepts. This is adequate as one starts to face difficulty with the process of developing a meaningful hierarchical organisation. The learners needs to keep in mind that they have to view the construction process of the concept map on a work-in-progress basis; learners will have to revise the concept map till they achieve mental satisfaction.

Various aspects of concept map construction:

Research. It is an exploratory stage in which the learner should apply a number of investigative methodologies, like trial and error, to bring out a well-developed concept map. This enables the learners to come up with a concept map which includes all the aspects from related areas of the central idea, making it a more relevant one.

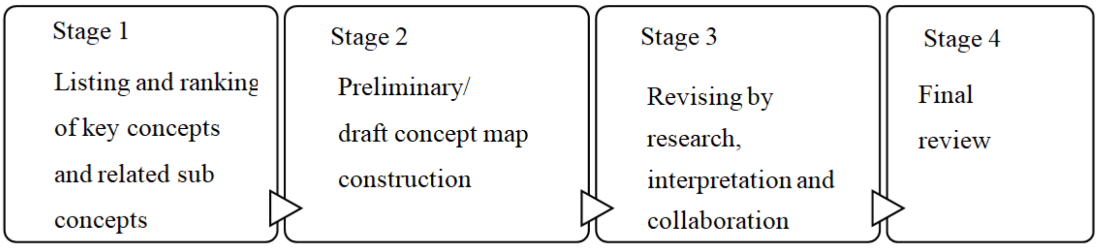
Interpretation. It is in this stage; the learner requires critical thinking skills and application of higher-order concepts for the analysis of the concept map. Super concepts, sub-concepts, and examples are used for organising the knowledge structure of the students. Students may use previous concepts as well on the map, which will provide multiple perspectives to construct the map.

Collaboration. Collaboration can be considered as "an act of sharing of knowledge or creativity for the group's profit as well as the individual gain in a particular matter". Concept map as a tool cultivates collaboration among learners in multiple ways for the knowledge structure in the cognitive domain. In the process of constructing concept maps, students will intellectually and emotionally cooperate among them by transferring their ideas and connecting or rejecting them with concept maps. It is thus clear that the activity of concept map construction offers opportunities for students to share their insights and perspectives on a particular subject matter.

Finally, once the map is constructed completely, it is reviewed based on appearance, accuracy, thoroughness and organisation.

Figure 5

Steps for the Construction of Concept Maps



Concept Map Construction – Role of Teachers

Firstly, it is the teacher's role to select which unit or lesson has to be considered for concept map construction. Suggesting relevant materials (For eg. Textbooks, reference books, software, etc.) and making them available (if possible) can facilitate the students in the concept mapping construction process. To achieve the expected objectives/learning outcomes of the course, the teacher must scientifically plan the concept map activity. Sample concept maps must be prepared in prior by the teacher, which helps to classify key concepts (super concepts) and sub-concepts, to get a clear idea about positions of concepts and the model of concept hierarchy and the kind of concept map. In the classroom, the teacher can act both as a facilitator of the process, giving freedom to learners for sharing their ideas, knowledge, cooperation and collaboration or as a guide by drawing the concept map on the blackboard throughout the process. Attractive teaching aids, such as colourful concept blocks. Thus, teachers play an important role in obtaining a perfect concept map satisfying both students and teachers.

Theoretical Aspects of Integration of Concept Mapping with PBL

Concept Mapping (CM) has been implemented in Problem-Based Learning in medical and nursing education to enhance the quality of students' learning processes (Hsu, 2004; Johnstone & Otis, 2006; Pinto & Zeitz, 1997; Rendas et al., 2006). By implementing CM in the PBL process, students have to visualise their prior knowledge in the form of a concept map, which helps them to separate what is already known from what needs to be researched to better understand the problem and its underlying mechanisms (Johnstone & Otis, 2006). By reactivating and extending on prior knowledge, CM is anticipated to facilitate and improve the pace of achieving learning goals. Since CM is anticipated to prompt vigorous discussion and detailed analysis of the concepts, and how they are interconnected, we would expect to find more meaningful and adequate learning goals in groups working by integrating concept mapping strategy. An indicator of the efficacy of CM strategy in the PBL method is the closeness between the learning goals generated by students and the learning goals that are set by the problem designers. It is the aims of curriculum and module objectives which sets boundaries for problem designers in setting the learning goals. Problem designers have to function within the constraints of the module theme and the module objectives by initiating a PBL process that ultimately results in meeting the performance goals of that particular educational unit. The proposed learning goals as listed by the problem designers are not essentially exhaustive or exclusively correct, but they are considered to be a valid criterion for assessing the performance showcased by PBL groups. Research on the correspondence between learning issues generated by PBL groups and the faculty objectives showed an average overlap of 64% (Dolmans et al., 1993; Dolmans et al., 1995). Also, employing concept mapping avoids students from jumping to learning goals by spending too little time and attention on the PBL process. The amount of time spent by students on the learning process is a necessary prerequisite for making significant learning gains (Koury et al., 2009). Research on the different phases in the PBL process shows that each phase influences the next phase, and learning shows a cumulative pattern (Yew et al., 2011). It provides insight into the time students invest in working on a problem as an indicator of the amount of attention students pay to active cognitive engagement in PBL (Rotgans & Schmidt, 2011; Zwaal & Otting, 2010). Research by (Kassab & Hussain, 2010) has shown that the quality of students' concept maps increased as students progressed from year two to year four in a problem-based curriculum.

PBL using the KWHLAQ Strategy Interlaced with Concept Mapping in a Teacher-Student Shared Inquiry Paradigm

According to McCombs (1991), students' self-directed learning will lead them to understand the responsibility and benefits of their thinking and the value of self-regulated learning strategies. Barell (2007) stated that when teachers allow students to take part in making decisions about what and how to study, they are helping them learn skills to identify, analyse, and solve their problems. Thus, the contemporary education system strongly demands creative changes from teacherdominated strategies to more student-centred strategies. Teacher and student shared inquiry using the KWHLAQ technique emphasises students' self-regulated learning rather than teacher-directed learning. In this strategy, students begin to direct some of their learning. It is a shared decision-making process. In Barell's (2007) view, with teacher-student shared inquiry, students begin identifying some of their curiosities, some of the questions they think are important and worth investigating. Thus, the teacher-student shared inquiry process leads to intellectual challenges. This involves the following processes:

What do we think we know? Students create a concept map during what we think we know. Thereby identifying prior knowledge and misconceptions about the concept

What do we want? The teacher has an opportunity to help students analyse complex issues and develop a concept map about them. Students relate one thing to another, make connections; they are seeking and finding out similarities.

How will we go about finding out? Ask students to draw a concept map to find their answers and how to organise the classroom for a serious investigation.

What do we expect to learn? Using concept maps, students begin to relate what they think they already know, followed by searching for relationships and patterns.

How will we apply what we have learned? Teacher makes the concept map in their teaching and search for connections in one way of making ideas more meaningful and connecting with other subjects and to personal lives.

What new questions do we have following our inquiry? Using a concept map helps students to organise more questions about new areas of knowledge.

Review of Related Studies

Studies Related to Problem-Based Learning

Kaur and Kaur (2025) conducted research to analyse the efficacy of the Problem Based Learning approach in teaching economics at the secondary school. During the research, a total of 680 CBSE-affiliated secondary school students were selected who showed significant improvement in achievement scores after being taught using the PBL approach. The study concluded that PBL helped enhance the understanding of economics concepts.

Dumbuya (2024) conducted a study to analyse the effect of integrating the PBL approach into secondary education curriculum development with a focus on enhancing critical thinking and problem-solving skills, particularly in STEM subjects. This research examined various case studies and empirical data. The research put forward a framework for effectively integrating PBL in diverse classroom settings. The findings suggest that PBL is more effective in engaging students and improving outcomes than traditional methods of teaching

Gumisirizah et al. (2024) carried out a study to examine the effect of PBL approach on students' problem solving ability in physics. A quasi-experimental design was implemented with 829 lower secondary students (aged 13-15) from 8 schools in Uganda. Students' problem-solving skills were assessed before and after the teaching learning process of a physics chapter, and the analysis revealed that there was a substantial improvement in problem solving ability in the PBL treatment group compared to the control group.

Erdem et al. (2024) conducted a second-order meta-analysis to evaluate the impact of the PBL approach on student outcomes in higher education. By analysing results from 20 first-order meta-analyses, it was found that the PBL approach significantly improves critical thinking, theoretical knowledge, student attitude and satisfaction.

Li et al. (2024) carried out research to analyse the merits and demerits of PBL in orthopaedics education. During the research, the students under consideration showed higher levels of interest and satisfaction in the PBL teaching group than in the traditional teaching group. This research concluded that the PBL teaching method can increase knowledge scores, procedural skill scores and clinical skill scores of students in Orthopaedics education.

Mualimah (2024) carried out a study on the implementation of problem-based learning methods to improve the Fiqh learning achievement of Zakat Material in 5^{th} – grade Jakarta students for the 2022-23 academic year. This study concluded that the PBL method has a positive effect on the learning motivation of 5th-class students.

Marra et al. (2024) conducted a study on the theoretical foundation of Problem-Based Learning. The researchers address the theoretical foundations of PBL, which in turn helps the readers to understand how the application of PBL can be effective.

Khoirudin et al. (2024) conducted research aimed at determining the effect of the problem-based learning method in improving social interaction abilities of Islamic Elementary School students. Under this research, data was taken through documents and questionnaire scores and through analysis, they found out that the PBL method can easily and quickly improve students' social interaction skills.

Ahmad et al. (2024) conducted research aimed at studying the impact of problem-based learning on the mathematics achievements of elementary students. The result of this research indicates an improvement in the achievement of the experimental group following the Problem-Based Learning method.

Anggraeni et al. (2023) researched the effect of problem-based learning in fostering critical thinking skills. The data collected in research focused on the analysis of the problem-based learning model in critical thinking skill development in the field of social science. This study concluded that training through the problem-based learning method can aid students in cultivating critical thinking skills.

Samosir et al. (2023) conducted a study aimed at capturing the research landscape related to the problem-based learning method in students at the middle school level from 1998 to 2023.

Trullas et al. (2022) conducted a study on the effectiveness and usefulness of PBL methodology in undergraduate medical teaching programs. This research found that PBL is an effective methodology for medical education.

Dermentzi et al. (2022) conducted a study among university students on the use of the problem-based learning method to teach open data skills. Findings of this study suggest that the PBL method is suitable for open data education. This study also put forward principles which aim to guide instructors on how they can effectively integrate PBL into open data skill teaching.

Musalamani et al. (2021) examined the effect of School-Based Cooperative Problem-Based Learning (SB-CPBL) on the science attitude of eighth-grade students in Jordan. They found out that there was a notable improvement in the attitude of SB-CPBL students towards science.

Sari et al. (2021) examined the effect of Problem-Based Learning on problem solving and scientific writing skills. The study was conducted on 62 students and concluded that the utilisation of the PBL method has a significant effect on problem-solving and scientific writing skills.

Susanti et al. (2020) conducted a study on the effects of Problem-Based Learning on the mathematical communication skills of Indonesian junior high school students. This research found that the effect of PBL on mathematical communication skills is 0.791.

Ali (2019) conducted a study to analyse the PBL approach as a student-centred approach that uses real-world, complex, and open-ended problems to promote active learning. A descriptive analysis was done based on literature review and pedagogical reflections, and it was found that PBL is both a teaching method and curriculum approach that enhances critical thinking, problem-solving, communication and lifelong learning skills.

Zakaria et al. (2019) conducted a study which involved a systematic review to examine the effect of the PBL approach in various educational disciplines. The review was based on 43 peer-reviewed and full-text articles published between 2015 and 2018, which were sourced from ERIC and Google Scholar. It was found that 95 per cent of reviewed studies reported a positive impact of the PBL approach on teaching learning outcomes, suggesting it as an effective alternative to traditional methods.

Malmia et al. (2019) conducted a study to determine the effect of Problem-Based Learning on the improvement of learning outcomes of class 11 chemistry students. The results based on inferential statistics showed that there is an increase in the average student's value who were taught using the PBL method.

Jabarullah and Hussain (2019) carried out a study to examine the impact of PBL on engineering students of a technical university in Malaysia. Students under research showed better response to PBL teaching methods, as proved by improved performance in written and lab assessments.

Park and Il-Soo (2019) carried out research using a meta-analysis technique to examine the outcomes of problem based learning strategies on the problem-solving skills of a group of students in Korea. In this research, PBL strategies were found to be more effective in problem-solving skills of students in the Mathematics course. Also, this research recommended that teachers should learn how to implement PBL strategies in the classroom environment.

Hendriana et al. (2018) researched to analyse the effect of problem-based learning in enhancing mathematical problem-solving ability (MPSA) and self-confidence (MSC) of students. The study found that the students who received treatment with PBL strategies obtained better results in MPSA and MSC than other students taught by conventional teaching.

Argaw et al. (2017) conducted a study to determine the impact of problem-based learning in improving students' problem-solving skills and motivation building in Physics. Data was collected through a problem-solving inventory test and a motivation scale. This study came to the conclusion that the PBL method has to be adapted carefully in schools to improve student achievement. The influence of the PBL strategy on students' motivation in physics remains vague.

Prayekthi (2016) researched the effects of the PBL model vs the Expository Model and Motivation on student achievement in Physics Learning at the senior high school level. This study shows that the average of students' physics learning results at the senior school level (Class XI) is higher for those who were taught in the PBL model than those given the expository model of learning.

Balim et al. (2016) conducted a study on the effects of concept cartoons and problem-based learning on students' inquiry learning skills and the extent to relating knowledge to daily life. The data analysis in this research showed that inquiry learning skills improved in the experimental group, which followed PBL strategies.

Alreshidhi and Khallaf (2016) researched to investigated the impact of problem-based learning strategies in Mathematics education in Saudi Arabia. This research found that the PBL strategy of teaching is far better than traditional methods of teaching in improving the knowledge application (among 3rd-grade students). Students' interest and confidence to learn maths were improved by using a PBL strategy. However, this research couldn’t find any evidence for PBL improving students' maths performance among 8th-grade students.

Etiubon and Ugwu (2016) designed a study to analyse the effect of PBL strategies on academic achievement in thermodynamics of undergraduate students (1^{st} year) of the University of Uyo, situated in Nigeria. This study found that the students who were taught through the PBL approach obtained higher scores. This research recommended that teachers take initiative in using methods like PBL in science teaching, which are activity-based teaching methods.

Studies Related to Concept Mapping

(focused on achievement and attitude towards science education)

Veiga et al. (2025) carried out a study to validate the usage of concept maps as an evaluation tool in mechanical and industrial engineering education. The study is based on qualitative analysis of concept maps and quantitative comparison with a control group of 79 students. Data were collected using rubrics, self-assessment surveys, and questionnaires. The findings revealed that concept maps effectively reflect students’ understanding and are an effective tool for evaluating student learning outcomes.

Veiga, Gil-Del-Val, Iriondo, & Eslava (2024) presented an experimental work developed to find the extent to which the concept mapping strategy helps a person in learning mechanical and industrial engineering. This research found the positive effect of the concept mapping strategy in the teaching-learning process.

Alharbi (2024) attempted to understand the effectiveness of concept mapping in enhancing digital concept development among female undergraduate students enrolled in a computer skills course. This research found concept mapping to be a 'potent instructional approach'

Jackson et al. (2023) conducted a study on the possibility of concept mapping as an assessment tool in engineering education. This research concluded that all types of concept mapping scores were useful for better learning outcomes.

Evans and Jeong (2023) attempted to evaluate the use of concept maps as an assessment tool in a university-level mathematics course with a total of 219 students. The study mainly aimed to examine how the concept mapping process is related to academic achievement and assessment. Hierarchical multiple regression analysis was used, in which the authors of this study found that concept mapping predicted final exam scores and students' emotional regulation abilities. The findings revealed that concept maps can be used to assess unique aspects of the conceptual understanding that are not measured by conventional assessments, and also, the concept maps promote a positive emotional engagement among learners, resulting in increased perseverance and deep learning. This study highlights the multiple roles of concept mapping in both cognitive and affective dimensions in the mathematics learning process.

Kasumu (2022) carried out a descriptive survey study to evaluate the benefits and challenges of using the concept mapping technique as a teaching strategy in a higher education scenario. The research was conducted among 100 teaching practice students from the Federal College of Education (Technical), Omoku. Data was collected using a structured 30-item questionnaire, having a reliability coefficient of 0.72. The analysis through mean, standard deviation, and Z-test revealed that the concept mapping technique favours meaningful learning by equipping students to relate new and existing knowledge, thus promoting deep information processing and critical thinking. This study concluded that the concept mapping technique is a beneficial tool for cognitive strategy and suggested its adoption by teachers to promote conceptual understanding and student engagement in higher education settings.

Achor and Bileya (2022) conducted a study to determine how the concept mapping strategy enhances students' achievement in Physics relative to the guided discovery method. Research findings show that concept mapping strategy is effective in enhancing students' achievement in Physics.

Lin et al. (2022) studied the effect of concept mapping as a teaching-learning strategy to improve critical thinking, conceptual understanding of theoretical concepts, confidence and motivation among baccalaureate nursing students. This study, conducted in Taiwan, was done among 20 nursing students of the course "Evaluation and Analysis of Adult Nursing Cases". Data were collected using semi-structured interviews and 100 reflective reports. The study concluded that the usage of concept maps encourages deeper learning and motivation in the nursing education learning process.

Kusumadewi et al. (2022) conducted a descriptive analysis to examine the effect of concept maps in enhancing the students' conceptual understanding and creative thinking analysis. In this study, data were collected through questionnaires, concept map assessment rubrics and interviews. It was found out that concept maps are effective learning tools which contribute positively to meaningful learning, student attitudes and academic achievement.

Research was carried out by Ahmed et al. (2021) aimed to determine the effects of concept mapping on student achievement in the Biology subject of senior schools in Lagos state, Nigeria. This research recommends that teachers adopt the use of concept mapping in teaching senior school Biology.

Almulla and Alamri (2021) carried out a study to examine the effectiveness of using concept mapping as a tool in enhancing students' motivation as well as academic achievement, specifically in the context of education for sustainability. The data was obtained from a total of 247 students who used concept maps actively in their learning process. The findings of this study revealed that the conceptual mapping technique has significantly improved students' understanding of complex topics, as well as improved critical and analytical thinking, and has a positive impact on improving motivation and academic performance.

Lafave et al. (2021) investigated the effectiveness of concept mapping as a pedagogical tool in teaching evidence-informed practice (EIP) competencies to undergraduate students of a health care program. The study was conducted with 15 students in a research methods course where a pre-test-post-test mixed-method design was adopted, comparing concept mapping to the traditional note-taking method. Results showed that concept mapping resulted in significantly deeper understanding of EIP, and it was also found out that concluded that concept mapping serves as a reliable tool for assessing the competency of students in evidence-based healthcare education.

Mahmoud et al. (2020) conducted research on the impact of concept mapping skills on the academic achievement of paediatric nursing students compared to traditional nursing education. This research suggested incorporating concept mapping skills as a learning strategy in nursing education.

Khrais and Saleh (2020) carried out a quasi-experimental type pre-test-post-test study, which involved 115 Jordanian nursing students to examine the effect of concept mapping on improving critical thinking skills. Students were divided into two groups, of which one received concept mapping instruction, while the other was taught using traditional lectures without the concept mapping technique. Results of this study revealed that students who participated in concept mapping integrated classes scored better in critical thinking assessments compared to those students in the traditional lecture-based group. Thus, the study concluded that concept mapping is effective in nurturing critical thinking abilities compared to conventional teaching methods. This study recommended the integration of concept mapping into curricula.

Woldeamanuel et al. (2020) carried out a quasi-experimental study to examine the effectiveness of the concept mapping technique in the teaching and learning process of Grade 8 students' conceptual understanding of photosynthesis. For this purpose, a total of 103 students were selected randomly and they were divided into two groups: experimental group (concept mapping) and control group (lecture) respectively. The post-test scores revealed a significant improvement in conceptual understanding of photosynthesis in those in the group taught using concept mapping when compared to the traditional lecture group. This study recommends the integration of concept mapping strategies in science curriculum as well as teaching practices for improved student learning outcomes.

Bilik et al. (2019) carried out a study to examine the effect of web-based concept mapping education in improving concept mapping skills and critical thinking of nursing students. A study was conducted with second-year nursing students in Turkey, dividing them into two groups in which one group received online concept mapping training, and the other group didn't.

Chen and Hwang (2019) carried out a quasi-experimental study to examine concept mapping-based flipped learning strategy on EFL students' (English as a Foreign Language) spoken English skill and critical thinking skills. The study was conducted among 72 students, who were divided into 2 groups, viz., experimental (n=37) and control (n=35) groups. In the experimental group, learners were given the activity to create concept maps after class and then were exhorted to use them for organising their responses for speaking tasks. At the same time, the control group was based on conventional learning methods. Findings from the post-test revealed that the experimental group performed well showing better outcomes in comparison to the control group in the aspects under consideration, such as speaking skills and critical thinking skills. This study concluded that implementing a concept mapping strategy in a flipped classroom setting is effective in enhancing EFL learners' speaking skills and critical thinking.

Bii et al. (2019) researched the effect of concept mapping as a teaching strategy on students' achievement and attitudes towards mathematics in selected secondary schools in Kenya. The results suggested that the teachers incorporate the concept mapping tool while teaching.

Gaikwad (2018) conducted a study to examine the effectiveness of concept mapping in the academic achievement of class 11 students studying the human nervous system in integrated science. A total of 120 students were divided into two groups; control and experimental groups respectively. The analysis of pre-test and post-test assessments revealed that concept mapping had a positive impact on student achievement.

Llinas et al. (2018) conducted a study to examine whether concept maps can be used as a tool for quantitative assessment of learners' comprehension in physics, particularly within an engineering course which covers the topic "electrostatic interactions". The study was conducted among 47 first-year engineering students who were given the task to construct concept maps based on the content given. This was followed by an assessment of constructed maps using a newly designed 'quantitative and qualitative evaluation method'. Obtained scores after assessing concept maps were compared to the traditional multiple-choice exam results, and it was found that concept maps can serve as valid tools for quantitative assessment of learning in physics.

Yue et al. (2017) conducted a systematic review and a meta-analysis to examine the effect of concept mapping in enhancing critical thinking within nursing education. This study mainly aimed to assess whether concept mapping, compared to traditional teaching methods, improves the affective dispositions and cognitive skills associated with critical thinking, which are essential competencies in the aspect of nursing students ' clinical decision-making. Findings of this research study showed that concept mapping strategy is effective on improving nursing students' critical thinking skills and dispositions.

Patrick (2017) conducted a study to examine whether the use of concept mapping as a study skill can advantage students' achievement in biology. The researcher concluded that concept mapping can be adopted as a study skill which helps students to retain what they have learned in biology for a long time.

Naskar et al. (2017) conducted a study to examine the effectiveness of concept mapping in teaching Life Science at the secondary level in West Bengal. In this study, students were selected from a randomly selected school in Kolkata and divided into control and experimental groups. A validated life science achievement test was administered before and after instruction, and then the data were analysed using t-test statistics. The findings of this study showed that the students taught using the concept mapping approach performed significantly better than those instructed through traditional lecture methods. The study recommended the concept map as an effective teaching strategy.

Çömek et al. (2016) conducted a study aimed at determining the effect of concept mapping as a learning strategy in science classes on students' academic achievement and attitude. The results of this research indicated that concept mapping (pen and pencil method) has a positive effect on improving student achievement in science classes.

Chawla and Singh (2015) researched to study the effect of teaching through concept mapping in 11^{th} – grade students' chemistry subject. The results of this research indicated that concept mapping is a suitable tool for improving achievement in the Chemistry subject of 11th-grade students.

Sakiyo and Waziri (2015) conducted a study to investigate the effectiveness of concept mapping as a teaching method on student achievement in biology at the secondary level. This research recommends incorporating the concept mapping in the teaching of biology.

Studies Related to Concept Mapping in Problem-Based Learning

Both educational strategies can be combined for an effective learning experience for students, which helps them in deep understanding, self-reflection and skills of critical analysis, decision making. The main aim of Problem-Based learning is to make learners more active by creating connections and constructing knowledge through inquiry. Concept mapping can be regarded as the best tool to integrate with PBL. In problem-based learning integrated with concept mapping, the problem acts as the starting point of inquiry, followed by visual interpretation, activation and linking of previous knowledge, and development of a solution. In this process, initial concept map creation, updating of concept maps play a major role in enhancing problem-based learning steps.

Meidiana and Pertiwi (2024) carried out a study to investigate the effectiveness of integrating the Problem-Based Learning (PBL) approach with the

Concept Mapping strategy in promoting science literacy and discussion skills in senior high school students. The study involved a quasi-experimental design in which two groups were present - an experimental group which was taught using PBL and concept mapping strategies, and a control group which was taught using the traditional scientific learning approach. This study has concluded that integrating concept mapping into the PBL approach is an effective teaching and learning approach for improving students' conceptual understanding and discussion skills in a science education scenario.

Chunyan et al. (2024) conducted a study to assess the effect of concept mapping within Problem-Based Learning (PBL) in medical education. A qualitative analysis of concept maps was done, and the study revealed that the students in medical education benefit from concept maps in visualising and developing knowledge acquired through PBL sessions.

Plotz (2020) carried out a study to check on the validity of adopting concept maps as a tool for assessing the extent of conceptual learning, particularly within the scenario of problem-based learning. The study was conducted based on the observation of six selected students over more than a year. Using a pre-test post-test scheme, students' concept maps were taken for comparison with a preset master map, and the obtained findings were evaluated along with traditional assessment formats such as interviews and written tests. The final results revealed that concept maps may fail to evaluate deeper conceptual understanding. Thus, the study shares the doubt about the reliability of concept maps as a standalone measurement tool for assessing conceptual learning.

Fitrianingsih et al. (2020) carried out research, "Concept map and problem-based learning", aimed to understand the correlation between concept map scores of students and problem-based learning strategy. This research found that the implementation of PBL will increase the percentage of concept mapping scores.

Nukman et al. (2018) conducted the study “The Effect of Problem-Based Learning Model with Concept Map on Problem Solving in Social Science Learning of the Fourth Grade Students SD Negeri 189 Pekanbaru”. The results showed the positive effect of integrating concept mapping with PBL on problem-solving ability in learning social science.

Chan (2017) conducted research aimed at exploring the application of concept maps as an educational tool in the problem-based learning process. The researcher explored the possibility of using concept maps as a learning activity in a PBL environment. This study showed how concept mapping strategy could be integrated to a PBL environment to enhance the students' creativity as well as to motivate them in learning. This study found that the adoption of concept maps in a PBL environment can be seen as an effective instructional strategy to motivate student to learn, participate actively, and nurture their creativity.

Hung and Lin (2015) conducted a study aimed at using concept mapping in the problem-based learning process to understand the knowledge structure developed in PBL. This research helped to understand the strong knowledge acquisition and conceptual understanding. This study gave an outline on how concept maps to be implemented in a PBL environment and also suggested the use of concept maps for motivating students to learn, actively participate and nurture creativity in the PBL process.

Summary of Theoretical Claims

Summary of theoretical claims are given in Table 2

Table 2

Summary of Theoretical Claims

Theoretical Claim	Theoretical Basis
Concept Mapping Strategy in Problem-Based Learning has a positive impact on enhancing the quality of students' learning processes	Integrating concept mapping into the PBL approach is an effective teaching and learning approach for improving students' conceptual understanding and discussion skills in a science education scenario. (Meidiana & Pertiwi, 2024)
	Chunyan et al. (2024) conducted a study to assess the effect of concept mapping within Problem-Based Learning (PBL) in medical education. A qualitative analysis of concept maps was done, and the study revealed that the students in medical education benefit from concept maps in visualising and developing knowledge acquired through PBL sessions.
	The Effect of Problem-Based Learning Model with Concept Map on Problem Solving in Social Science Learning of the Fourth Grade Students SD Negeri 189 Pekanbaru was studied and results showed the positive effect of integrating concept mapping with PBL on problem-solving ability in learning social science. (Nukman et al., 2018)
	Use of concept maps in a PBL environment can be seen as an initiative to motivate student to learn, participate actively, and nurture their creativity.(Chan, 2017)
	Concept maps can be implemented in a PBL environment for strong knowledge acquisition and conceptual understanding and also suggests the use of concept maps for motivating students to learn, actively participate and nurture creativity in the PBL process (Hung & Lin, 2015)
	Students using CMs (in PBL environment) for their study and revision would perform better on their assessment tasks than those who did not (Johnstone & Otis, 2006)
	Concept mapping as a tool enhances the problem-based learning process (Zwaal & Otting, 2010)

Conclusion

The education system is getting modified progressively, and it is at this time, the new educational approach of integrating PBL with Concept Mapping has its relevance. Utilising the strength of both strategies has a promising impact on educational outcomes. The researcher made an attempt to find studies/research related to the topics under consideration. This helped to understand the scope and relevance of PBL and Concept Mapping Strategy, as well as the integration of both in the field of education. The majority of the research found positive effects in implementing PBL, CM & PBL with CM in education, irrespective of the field of education.

Research gaps observed while reviewing are listed below:

1. The study of the incorporation of PBL with Concept Mapping can be seen to be limited and hence needs to be considered for advanced research.
2. Less research studies are conducted on PBL, Concept Mapping & Concept Mapping with PBL in the Indian context, and hence we can say that it is in its infancy stage in India, resulting in a research gap. Most of the researches are seen to be conducted internationally.
3. Implementation of the KWHLAQ strategy in PBL is rarely seen in past research.
4. The effect of PBL, Concept Mapping and PBL with Concept Mapping in Physics as well as in school education is less explored. Most of the past research is in the field of medicine and engineering.

The researcher thus decided to conduct his research on the topics under consideration for obtaining results which play a potent role in decreasing the research gap and contribute to the development of a new educational strategy.

Chapter 3

METHODOLOGY

- ***Variables of the Study***
- ***Objectives of the Study***
- ***Hypotheses formulated for the study***
- ***Tools Used in the Study***
- ***Method Selected***
- ***Experimental Design of the Study***
- ***Sample Selected for the Study***
- ***Experiment Conducted to Collect Data.***
- ***Statistical Technique Used in the Study***
- ***Conclusion***

METHODOLOGY

"I think you can have a ridiculously enormous and complex data set, but if you have the right tools and methodology, then it's not a problem."

– Koblin

The accomplishment of any research relies on the stability of the method adopted and the training that the investigator receives. Methodology explains the method adopted and the researcher has used for collecting, organising and analysing the data. Best (1996) has emphasised the importance of methodology, stating "Research may be defined as the systematic and objective analysis and recording of controlled observations that may lead to the development of generalisations, principles or theories resulting in prediction and possible ultimate control of events". Research methodology can be regarded as an organised way of identifying and designing the procedure to find solutions to the expected problems associated with the research.

The researcher investigated the effect of Concept Mapping Strategy in Problem-Based Learning on Achievement and Attitude towards Physics among XI students of Narokkavu Higher Secondary School, Narokkavu, Kerala, India. In this chapter, the researcher explains the system of procedures that were followed to carry out the investigation and reach a conclusion. This chapter provides detailed explanations of the method selected, the experimental design adopted for the study, the variables of the study, the objectives and hypotheses of the study, the description of the tools selected to collect data, the sample selected for the study, the experimental procedure and the statistical techniques employed in the study.

Variables of the Study

Variables can be considered as the conditions or characteristics that the researcher may manipulate, control or observe for the conduct of research study.

Independent Variables

The independent variables can be defined as the conditions or characteristics that the researcher manipulates or controls in his or her attempt to find out their relationship to the observed phenomena. Here, in this study, instructional strategy (Concept mapping strategy in Problem-Based Learning/Problem-Based Learning without Concept mapping strategy) was treated as an independent variable.

Dependent Variables

The dependent variables can be defined as the conditions or characteristics that may appear, disappear or varies as the researcher introduces, maintains or changes the independent variables. Also, the dependent variable is the outcome upon which the researcher compare the independent variable in an experiment. Here, in this study, achievement and attitude towards Physics are the dependent variables

Controlled Variables

In this study, the controlled variables are Non-Verbal Intelligence and Logical Mathematical Intelligence.

Objectives of the Study

The main objectives of the study are,

1 To find out the effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning/Problem-Based Learning without Concept Mapping Strategy) on achievement in Physics of Higher Secondary School students.

2 To find out the effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning /Problem-Based Learning without Concept Mapping Strategy) on attitude towards Physics among Higher Secondary School students.

3 To study the main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and Logical Mathematical Intelligence on Achievement in Physics for the total sample.

4 To study the main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning /Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on Attitude towards Physics for the total sample.

Hypotheses

The hypotheses formulated for the study are:

1. There will not be any significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) with nonverbal intelligence and logical mathematical intelligence as covariates on achievement in Physics among higher secondary school students.

2. There will not be any significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) with nonverbal intelligence and logical mathematical intelligence as covariates on attitude towards Physics among higher secondary school students.
3. There will not be any significant main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on achievement in Physics for the total sample.
4. There will not be any significant main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on attitude towards Physics for the total sample.

Tools and Materials Used in the Study

Different methods and procedures have been either adopted or developed to aid in the acquisition of data. These tools employ distinctive ways of describing and qualifying the data (Best, 1999). Data collection is essentially an important part of the research process so that the inferences, hypotheses, or generalisations tentatively held may be identified as valid, verified as correct or rejected as untenable (Koul, 1984).

To gather necessary data, the investigator prepared various tools. Following tools were employed for the collecting required data:

(1) Nonverbal Intelligence Test (Standard Progressive Matrices)
(2) Logical Mathematical Intelligence Test.
(3) Lesson Transcript based on Concept Mapping Strategy in Problem Based Learning
(4) Lesson Transcripts based on Problem-Based Learning without Concept Mapping Strategy

(5) Achievement Test in Physics

(6) Physics Attitude Scale

The details regarding the tools used for the study are outlined below.

Standard Progressive Matrices

Raven's Standard Progressive Matrices (SPM), which was published in 1938, is an examination of a person's capability at the time of the test to interpret meaningless figures presented for observation, see how they are related to each other, and reach a conclusion. By doing so, learners develop a systematic way of reasoning. This scale consists of 60 problems which are divided into five sets of twelve problems in each. The first problem self-evident as near as possible. The problems, which then follow, become progressively difficult to interpret, interrelate and conclude. The order of items, followed in the scale, provides a standard training for the learners in the way of working. The five sets, with twelve problems each, provide five opportunities for the learners to grasp the method and offer five progressive assessments of a person's capability for intellectual activity. To ensure constant interest and reduce fatigue, the figure in each problem is presented boldly, actually drawn in a pleasing way to look at..The reliability coefficients, as stated by Raven, vary from 0.80 to 0.90. Correlation ranged from 0.50 to 0.86 when the Stanford-Binet test was applied as a criterion.

Logical Mathematical Intelligence Test

The Logical Mathematical Intelligence test was adopted from the study Effect of Schema-Based Instruction on Solving Story Problems in Physics Among Higher Secondary School Students (Vijesh, 2019) developed by Vijesh K and Dr. Manoj Praveen G based on the Logical Mathematical Component of the theory of multiple intelligences proposed by Gardner (1983).

The items of this test were developed with an intention to measure thirteen components of logical Mathematical Intelligence, viz., 1. Classification 2. Logical pattern recognition 3. Logical diagram analysis 4. Coding and Decoding 5. Ordering 6. Direction sense 7. Information analysis 8. Drawing logical assumptions 9. Understanding the relationship between cause and effect 10. Analogy 11. Syllogism 12. Symbol manipulation 13. Computing ability.

Lesson Transcripts

In the present study, lesson transcripts were systematically designed by the researcher for both experimental group (based on Concept mapping strategy in Problem Based Learning) and the comparison group (based on Concept Mapping Strategy in Problem-based Learning). The first step in the designing of lesson transcripts was to select the desired topics for employing the instructional strategy which was done through vigorous analysis of class XI Physics curriculum prescribed by SCERT, Kerala. Based on this analysis, draft lesson transcripts, which includes the Problem Based Learning and concept map techniques, were prepared separately based on the different requirements for both experimental and control groups. The draft lesson transcripts were then subjected to expert validation by a panel consisting of Mrs. Renjini R, HSST in Physics, Narokkavu HSS, Mr. Abdul Samad (HSST in Physics, Govt. HSS Ambalavayal), and Mr. Midhun M (HSST in Computer Science, Narokkavu HSS). The expert panel assessed for content accuracy, pedagogical appropriateness, alignment with learning objectives, and clarity of instructions and provided constructive feedback. Based on the comments and suggestions provided by the expert panel, the transcripts were revised under the guidance of the research supervisor, Dr. Manoj Praveen G (Associate Professor, Department of Education, University of Calicut).

Lesson Transcripts based on Problem-Based Learning without Concept Mapping Strategy

A lesson transcript was prepared based on the KWHLAQ strategy in the Problem-Based Learning Approach.

Lesson Transcript based on Concept Mapping Strategy in Problem-based Learning

For an effective classroom teaching and learning process, the investigator prepared a lesson transcript based on the KWHLAQ Framework in the PBL approach by integrating the Concept Mapping Strategy into it.

Achievement Test in Physics

An achievement test is constructed by the investigator to find out whether the concept mapping strategy in problem-based learning and problem-based learning without the concept mapping strategy had any impact on the achievement and attitude of students in physics. For this purpose, the investigator pooled questions based on the selected concepts. As mentioned earlier 10 concepts were selected from the higher secondary physics. The test included all types of questions, like objectives, short-answer type, as well as essay-type items. The achievement test was constructed by keeping the revised Bloom's taxonomy in mind. Items were testing the attainment of the six levels of objectives, namely knowledge, understanding, applying, analysing, evaluating and creating (Anderson, 2001).

Planning

The preliminary step in developing this tool (achievement test) was a detailed analysis of content of the chapters "Motion in a Straight Line" and

"Motion in a Plane" presented in the NCERT Physics textbook of grade 11. On the basis of content analysis, the investigator identified various questions in the chapter and prepared a blueprint based on Revised Bloom's Taxonomy created by Lorin Anderson and David Krathwohl in 2001.

In the second step, the investigator developed various questions to be included in the achievement test by giving weightage to objectives, content and type of questions. This benefitted in developing the achievement test and a preliminary set of items. All items were then analysed for their appropriateness as well as meaningfulness through a consultation process with experts in Physics.

Item Writing. A draft of 21 questions was prepared based on the chapters "Motion in a Straight Line" and "Motion in a Plane" presented in the NCERT Physics textbook of grade 11, giving due weightage to objectives, content and type of questions. During the preparation of draft test, care was taken concerning the rules for construction of items, such as clarity, accuracy, and relevance of items.

The weightage given to different objectives is given in Table 3.

Table 3

Weightage to Objectives

Sl No	Objectives	No. of items	Marks
1	Remember	4	4
2	Understand	5	7
3	Apply	6	17
4	Analyse	3	4
5	Evaluate	1	3
6	Create	2	5
	Total	21	40

The weightage given to different content is given in Table 4.

Table 4

Weightage to Content

Sl No	Content	No. of Items	Marks
1	Path length & Displacement	2	3
2	Uniform motion & velocity time graph	3	5
3	Velocity & Speed	4	7
4	Instantaneous speed & Instantaneous velocity	1	1
5	Acceleration	2	4
6	Kinematics equations	1	4
7	Scalars & vectors	2	3
8	Vector addition	2	5
9	Projectile motion	3	5
10	Uniform circular motion	1	3
	Total	21	40

The weightage given to type of questions is given in Table 5.

Table 5

Weightage to the Type of Questions

Sl No	Form of Questions	No. of Items	Marks
1	Objective type	6	6
2	Short answer type	10	17
3	Essay type	5	17

Blueprint of Achievement Test in Physics is given in Table 6

Table 6

Blueprint of Achievement Test in Physics

Objectives	Remember			Understand			Apply			Analyze			Evaluate			Create			Total Questions	Total Marks
Form of questions Content	O	S	E	O	S	E	O	S	E	O	S	E	O	S	E	O	S	E		
Path length & Displacement				1 (1)				1 (2)											2	(3)
Uniform motion & velocity time graph		1 (1)			1 (2)						1 (2)								3	(5)
Velocity & Speed				1 (1)				1 (1)	1 (4)	1 (1)									4	(7)
Instantaneous speed & Instantaneous velocity				1 (1)															1	(1)
Acceleration		1(1)												1(3)					2	(4)
Kinematics equations									1(4)										1	(4)
Scalars & vectors		1(1)															1(2)		2	(3)
Vector addition					1 (2)				1 (3)										2	(5)
Projectile motion	1 (1)								1 (3)	1 (1)									3	(5)
Uniform circular motion																		1(3)	1	(3)
Total questions	1	3		3	2			2	4	2	1			1			1	1	21	
Total marks	(1)	(3)		(3)	(4)			(3)	(14)	(2)	(2)			(3)			(2)	(3)	(40)	

Item Analysis

Item analysis is the systematic estimation of the effectiveness of the individual items on a test (Brown, 1996). On the basis of item analysis, the investigator calculated the Item Facility (IF) value (also called as item difficulty index) and the item discrimination index of each item in the Achievement test in Physics. This test comprises the items, each of them having a weighted score. Item facility and item discrimination statistic of each item having weighed scores were calculated by following the item analysis procedure advocated by Brown (2000). A total of 21 achievement test questions were developed, and the item Facility Index Value and Discrimination Index Value (DI) were calculated.

The Item Facility (IF) value (item difficulty index) was calculated using the following formula given below:

$$Facility\ Index\ (FI) = \frac{\Sigma x}{N \times M_{max}}$$

$\sum X$ – The sum of the actual scores all students received for that item

N - Total students who attempted the item

M_{max} – Maximum possible score for the item

The Discrimination Index (DI) Value was calculated using the formula

$$Discrimintion\ Index\ (DI) = \frac{\Sigma x_H - \Sigma x_L}{N \times M_{max}}$$

$\sum X_H$ - Total score on the item for the high group

$\sum X_L$ - Total score on the item for the low group

N - Number of students in each group

M_{max} – Maximum possible score for the item

The investigator organized the total scores of responses collected from 100 students in descending order. The lower 27 per cent and upper 27 per cent of students' response sheets were considered which led to lower and upper groups with 27 students in each. The responses for each item in both groups were assessed and subjected to item analysis. The accepted range for Facility Index (FI) is from 0.4 to 0.8, and for Discrimination Index (DI) is greater than 0.3. The details of item analysis is given in Table 7.

Table 7

Data and Results of Item Analysis of Test for Assessing Achievement in Physics

Item Number	Facility Index(FI)	Discrimination Index (DI)	Selected or Not
1	0.72	0.37	✓
2	0.70	0.41	✓
3	0.74	0.33	✓
4	0.70	0.44	✓
5	0.70	0.37	✓
6	0.74	0.52	✓
7	0.72	0.37	✓
8	0.69	0.48	✓
9	0.74	0.41	✓
10	0.76	0.48	✓
11	0.65	0.43	✓
12	0.85	0.17	
13	0.64	0.41	✓
14	0.35	0.11	
15	0.64	-0.02	
16	0.53	0.51	✓
17	0.66	0.44	✓
18	0.54	0.51	✓
19	0.56	0.40	✓
20	0.53	0.34	✓
21	0.24	0.19	

Note. The tick mark indicates that the value agrees with the criterion for selection.

Reliability of the Tool

The reliability of achievement test was measured by employing test-retest method. For this purpose, a subgroup comprised of 30 students was selected by the researcher from the original sample of 100 students who had participated in item analysis. The same test was administered again to this subgroup of 30 students after one month of time and their answer sheets were collected and scored to calculate the correlation coefficient between two set of scores. The correlation value of 0.83 thus obtained indicates that the tool possesses high reliability.

Validity of the Tool

To ensure the content validity of the Achievement test, great care was taken in constructing the items, and input of various experts in this field was considered. To evaluate the concurrent validity of the test, it was then correlated with the scores obtained from a subgroup comprised of 30 students was selected by the researcher from the original sample of 100 higher secondary school students with their scores obtained in the unit test. The correlation coefficient obtained was .69, indicating that the developed achievement test has validity.

Physics Attitude Scale

A Physics Attitude Scale (PAS) was adopted from the study 'Development of Physics Attitude Scale (PAS): An Instrument to Measure Students' Attitude Towards Physics' (Kaur & Zhao, 2017) among Higher Secondary School students.

In the above-mentioned Physics Attitude Scale (PAS), there are sixty items under the following five factors: 1. Enthusiasm towards physics 2. physics learning, 3. physics as a process, 4. physics teacher, 5. Physics as a future vocation. Out of these 60 items, 27 are positive and 33 are negative statements. Each item is given with an opportunity for learners to give live responses ranging from strongly agree (S.A), agree (A), undecided (U.D), disagree (D), and strongly disagree (S.D). Students are required to read and analyse each item in the test in a careful manner and mark the response that they themselves feel as most appropriate. It is necessary to attend all the items, and this test has no specific time limit as well as no fixed right or wrong answers. The scoring system is as follows: Positive Statements (+ve): Strongly Agree (S.A) - 5, Agree (A) - 4, Undecided (U.D) - 3, Disagree (D) - 2, Strongly Disagree (S.D) - 1.; Negative Statements (-ve): Strongly Agree (S.A) - 1, Agree (A) - 2, Undecided (U.D) - 3, Disagree (D) - 4, Strongly Disagree (S.D) – 5.

Reliability

Physics Attitude Scale (PAS) developed by Kaur and Zhao (2017), adopted for the present study, was subjected to a recheck for reliability and validity. The significance of re-establishing the reliability and validity lies in the fact that and instrument that was developed in one context may not function in the same way with a different group of learners. Therefore, the scale was validated again with the present sample for ensuring its appropriateness for higher secondary students in Kerala. For the purpose of establishing criterion validity, the Physics Attitude Scale developed by Gürler and Baykara was also administered to the same group of students, and the correlation between the two sets of scores was calculated. This helped to confirm that the adopted PAS measured students' attitudes toward Physics in a consistent and dependable manner for the population of this study.

To re-establish the reliability of the Physics Attitude Scale, two methods were employed; they are: test retest and Cronbach's alpha (to test internal consistency). The test-retest method was carried out by administering the tool to 30 higher secondary school students was selected by the researcher from the original sample of 100 students after a one-month interval. The correlation coefficient between the two scores was obtained as 0.81, indicating the high reliability of the Physics Attitude Scale. Cronbach's alpha value found for the Physics Attitude Scale is .924, which suggests the Physics Attitude Scale has high internal consistency and hence the tool is highly reliable. The obtained Cronbach's alpha reliability coefficients of the five factors of the scale are given in the table 8 below

Table 8

Cronbach's Alpha Reliability Coefficients of the Five Factors of the Physics Attitude Scale

Sl No	Factor	Cronbach's alpha
1	Enthusiasm toward Physics	.759
2	Physics Learning	.755
3	Physics as a process	.817
4	Physics Teacher	.849
5	Physics as a Future Vocation	.857

Validity

For establishing criterion-related validity, the score obtained from the Physics Attitude Scale for a representative group of 30 higher secondary school students was selected by the researcher from the original sample of 100 students is correlated with the score obtained from the study "Development of an Attitude Scale for Physics Courses and a Review of Student Attitudes" developed by Gürler and Baykara (2020). The validity coefficient obtained is 0.75. The obtained correlation coefficient establishes high validity of the Physics Attitude Scale.

Method Selected

This study mainly aims to understand how integrating concept mapping strategy with Problem-Based Learning has effect on achievement and attitude towards physics, and also to study the main and interaction effects of instructional strategy and logical mathematical intelligence on the same. Hence the investigator has taken a decision to adopt an experimental method.

> *Experimentation is the classic method of science laboratory where elements are manipulated and effects observed can be controlled. It is the most sophisticated, exact and powerful method for discovering and developing an organised body of knowledge* (Best & Kahn, 1992).

Experimental Design of the Study

A research design is considered as a set of methods and procedures employed in collecting and analyzing the obtained measures of variables in the research problem. It allows the researcher to reach valid conclusions. The selection of a suitable experimental design depends upon the type of research, the type of variables and various limiting factors under which the experiment has to be conducted.

The educational factors to which the groups of students were subjected during the period of study were controlled, and the resulting achievement and attitude towards physics were observed for the present study. So, a quasi-experimental pre-test, posttest, comparison group design was employed for the study.

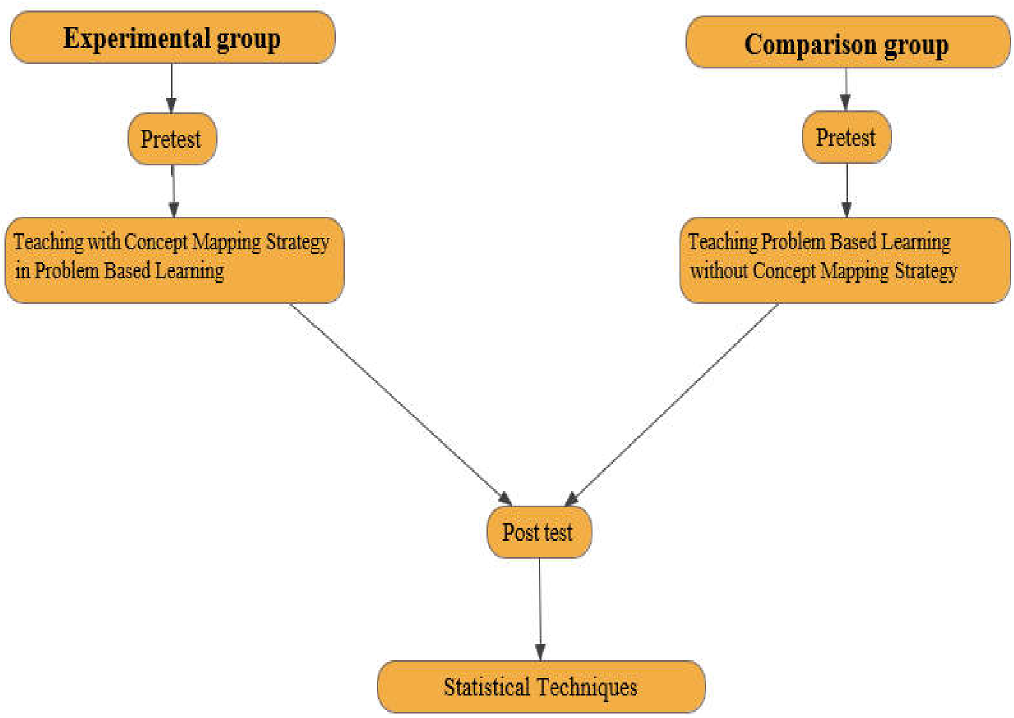
Table 9

Design of the Study

Stage	Experimental Group	Comparison Group
Pre-test	• Standard Progressive Matrices (non-verbal intelligence) • Logical- Mathematical Intelligence Test • Achievement Test in Physics • Physics Attitude Scale	• Standard Progressive Matrices (non-verbal intelligence) • Logical- Mathematical Intelligence Test • Achievement Test in Physics • Physics Attitude Scale
Treatment	• Teaching with Concept Mapping Strategy in Problem-Based Learning	• Teaching without Concept Mapping Strategy in Problem-Based Learning
Posttest	• Achievement Test in Physics • Physics Attitude Scale	• Achievement Test in Physics • Physics Attitude Scale

Figure 6

Design of Study - Visual Representation



In the design, two Higher Secondary Science classes were selected, of which one was chosen as experimental group and the second as a comparison group. The experimental group and comparison group were then subjected to Non-Verbal Intelligence Test (Standard Progressive Matrices), Logical Mathematical Intelligence test, Physics Achievement test and Physics Attitude Scale before treatment. After the treatment, the experimental group and control group were subjected to Achievement test and Physics Attitude Scale.

Treatment

The investigator introduced treatments to the experimental group for a specified time period of 2 months. The experimental group was given instructions through the Concept Mapping Strategy in Problem-Based Learning. The comparison group was taught through the Problem-Based Learning approach without the Concept Mapping Strategy.

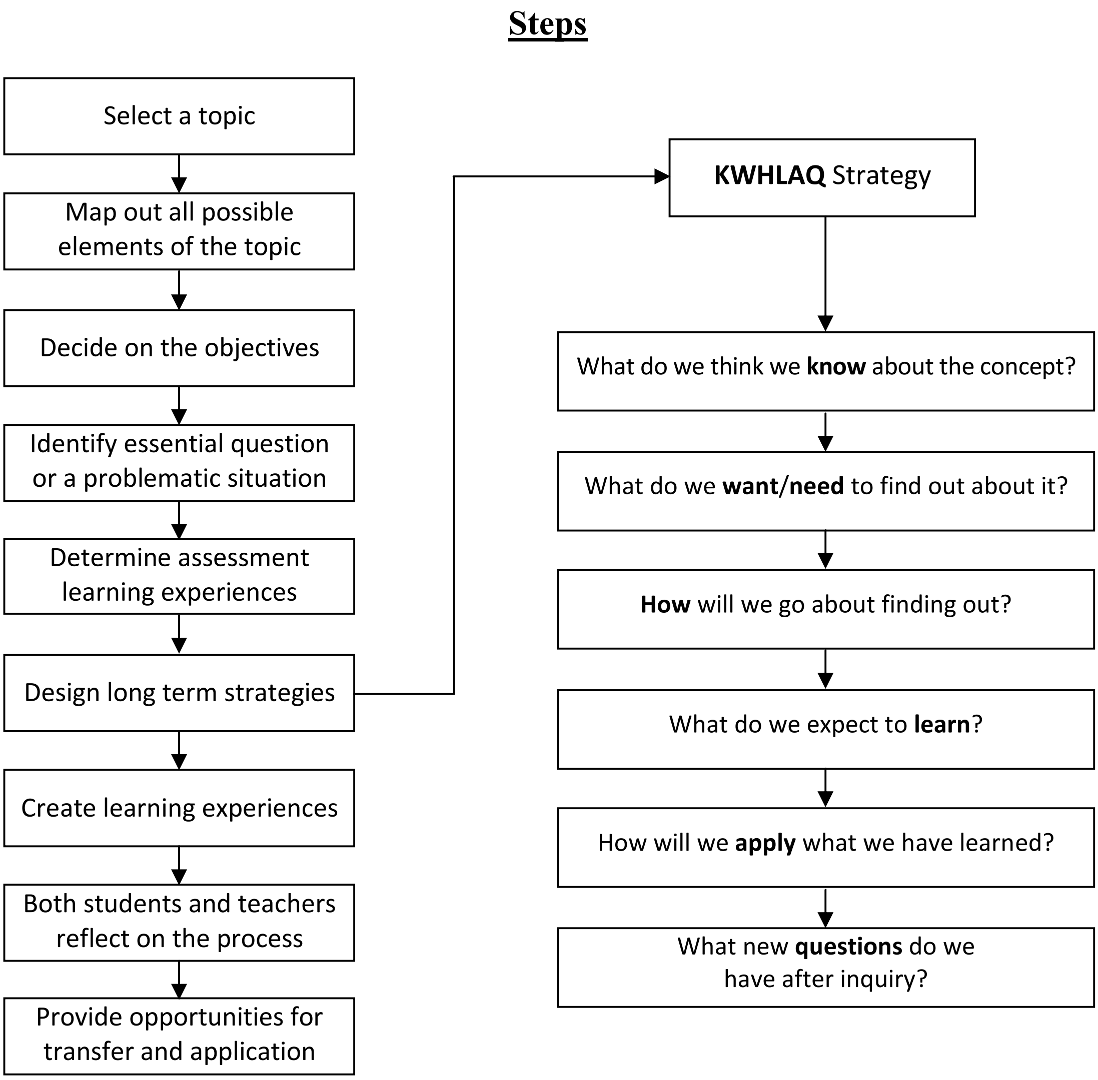
Plan of Action for Implementation of Problem-Based Learning Approach with and Without Concept Mapping Strategy

The investigator used two chapters, viz., motion in a straight line and motion in a plane, to teach the control group in problem-based learning without a concept mapping strategy. 20 lesson plans were prepared using problem-based learning without a concept mapping strategy.

Syntax of PBL using the KWHLAQ Strategy not Interlaced with Concept Mapping Strategy is given the following figure 7.

Figure 7

Syntax of Problem Based Learning without Concept Mapping Strategy



The Problem-Based Learning (PBL) approach without Concept Mapping strategy initiates by selecting a specific topic from Physics – such as Motion in a Straight Line – and identifying relevant concepts like displacement, velocity, acceleration, motion graphs, and kinematic equations. Teacher then sets learning objectives and then students are given with a real-life physics problem. Students carry out assessment and learning activities such as solving worksheets, numerical practice, and group discussions, supported by long term strategies. Students will discuss the problem, make predictions, solve numerical questions, interpret graphs, and present their reasoning. Reflection is built into the process, with both students and teacher reviewing how the problem was solved and what reasoning strategies were used. Finally, students apply the learned concepts to new everyday contexts and numerical problems reinforcing conceptual understanding. Throughout the process, the KWHLAQ framework guides learning, helping students articulate what they already know, what they need to know, how they will investigate, what they have learned, how they will apply it, and what new questions arise from their inquiry.

The investigator used two chapters, viz., motion in a straight line and motion in a plane, to teach the comparison group in the problem-based learning without a concept mapping strategy. 20 lesson plans were prepared using problem-based learning without concept mapping strategy.

Concept maps are essential tools for planning, teaching, and student concept constructions while helping to avoid misconceptions. It facilitates the students to fulfil high-quality and meaningful learning outcomes in the discipline of science. Maps provide concrete visual aids to help organise information before it is learned.

In concept mapping, concepts are arranged in hierarchical order following the principle of progressive differentiation. In the classroom, the teacher explains the relative position of key concepts, specific concepts, the interrelationship of concepts found in different segments and hierarchies. The learner moves from one concept to another in vertical as well as horizontal positions. A concept map can be developed for the entire course for a year or a semester or a single unit, or even a single lesson.

Problem-Based Learning is regarded as an instructional strategy in which the students are actively involved in the learning process through gaining experience in solving open-ended problems. This is a student-centred approach which facilitates the students to show active participation in the learning process, to think critically, and to apply new knowledge in real-world scenarios. In a problem-based learning approach, students are divided into groups, enabling them to identify what adequate knowledge they have to learn to solve a problem.

When the concept mapping strategy is integrated with PBL, we are creating an effective framework for learning as follows:

1. ***Better Understanding.*** Concept maps are helpful for students to visualise concepts, which simplifies the complex information as well as interlinks similar concepts, which helps them to identify knowledge gaps.
2. ***Organisation of Knowledge.*** Concept maps facilitate students to organise new information, update their knowledge, and integrate it with prior knowledge.
3. ***Communication and Collaboration***. Concept maps act as a common visual reference. It helps students to communicate their ideas for the construction of concept mapping, leading to strong collaboration among peer groups.
4. ***Self-Directed Learning***. As the concept maps help them to identify key concepts and their relationships, students will be able to focus on learning by themselves.
5. ***Assessment Tool***. Concept maps can be employed by educators to assess the comprehension level of students as well as their progress. Also, it helps the students to assess themselves by identifying the areas in which they are weak and need improvement.

In conclusion, the integration of the concept mapping strategy with PBL provides the students with a sophisticated learning framework. In this study, the investigator has used the KWHLAQ strategy for implementing the Problem-Based Learning method. It is explained below:

KWHLAQ Framework

The acronym KWHLAQ stands for the 6 stages of reflective inquiry. They are: K: What do I know?; W: What do I want to know?; H: How will I find out?; L: What have I learned?; A: How will I apply what I've learned?; Q: What new questions do I have? (Barell, 2006)

Stages of the KWHLAQ Strategy.

1. Know (K). In this stage, the learner identifies already existing knowledge related to the provided problem. This stage helps students to know the current understanding level, which serves as a beginning point for further learning

2. Want to Know (W). In this stage, students try to find what they want to know or what questions they have to answer to solve the provided problem. This is the stage which makes the students curious and actively participate in solving the problem.

3. How to find out (H). In this stage, students start to find ways and methods which are essential for collecting the adequate data to solve the provided problem. This stage inculcates research and information-gathering skills in students.

4. Learned (L). After the previous stage, students learn about the problem situation as well, and they reflect on what they have learned. This is the stage which helps to organise new knowledge and integrate it with existing knowledge.

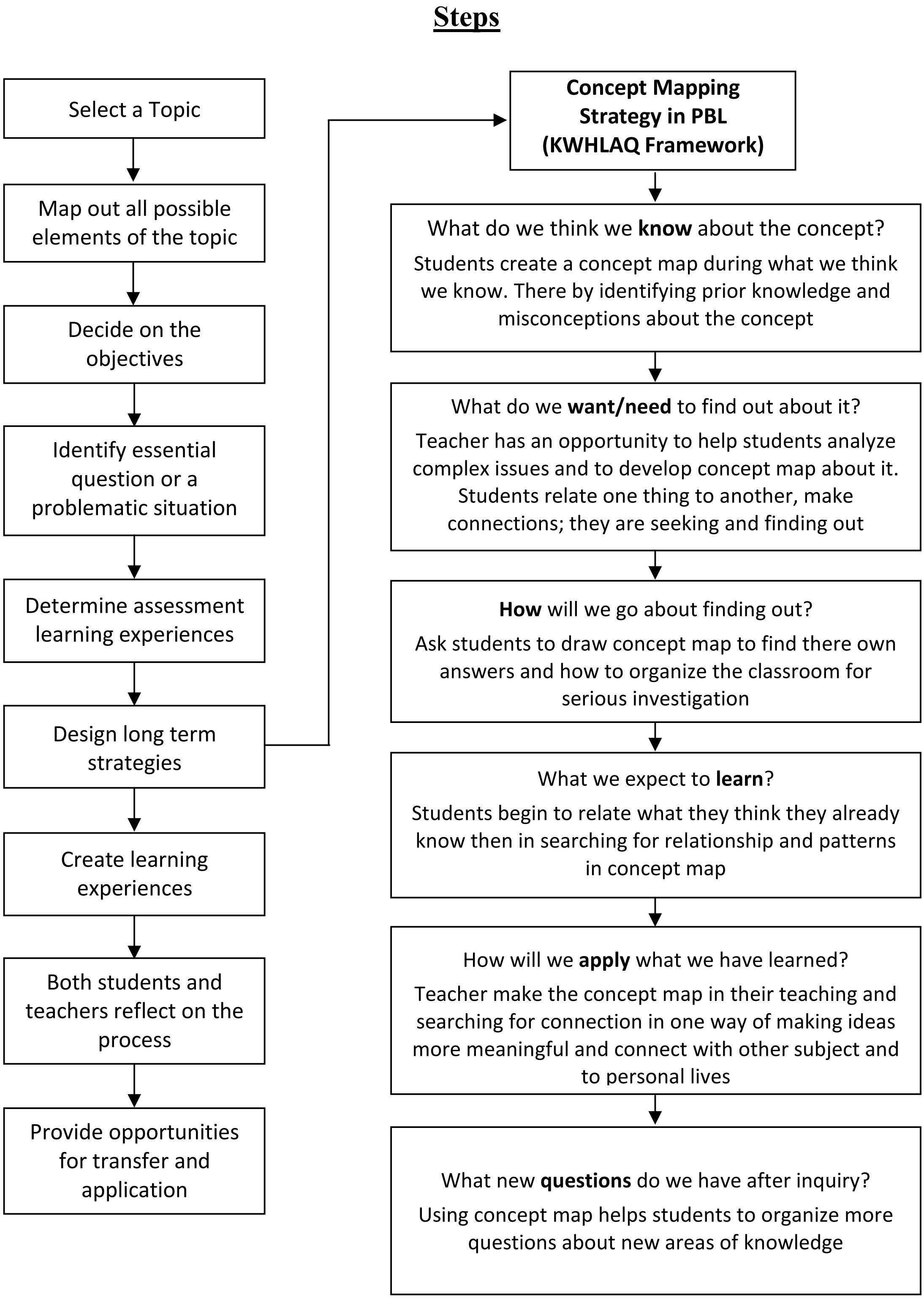
5. Apply (A). Students think about how new knowledge acquired in the previous stage can be applied in various contexts. This stage gives importance to practical application and the relevance of what they have learned.

6. Questions (Q). In the final stage of the KWHLAQ strategy, students frame new questions on the basis of what they have newly learned.

Syntax of PBL using Concept Mapping Interlaced with KWHLAQ Strategy

Figure 8

Syntax of Concept Mapping Strategy in Problem Based Learning



The Syntax of Concept Mapping Strategy in Problem-Based Learning approach initiates with selection of a desired topic from Physics such as Motion in a Straight Line, Motion in a Plane, or Laws of Motion, followed by identification of all relevant key concepts such as displacement, velocity, acceleration, vectors, graphs, and equations of motion. After this, the teacher sets learning objectives and introduces a real-life problem from Physics to initiate an inquiry. Students then engage in various assessment and learning activities such as concept maps making, worksheets, numerical problem solving, model building, and discussions. Designing long-term strategies include concept map strategy applied in KWHLAQ strategy. During the learning process, students analyse the given problem, identify the variables, predict the outcomes, construct (or revise) concept maps, and reflect with teacher feedback. Finally, students will apply the acquired knowledge to new contexts as well as use improved concept maps to answer higher-order questions.

Sample Selected for the Study

"Sampling is the process by which a relatively small number of individuals, objects or events in selected and analysed to find out something about the entire population or universe from which it was selected" (Harris, 1960).

The present study was carried out on a sample of 100 students (50 each) from 2 divisions in XIth standard of Narokkavu Higher Secondary School, Narokkavu, Malappuram (Dist). The investigator administered a non verbal intelligence test and a logical mathematical intelligence test, in order to get two equivalent groups; one of the two groups was randomly selected as the experimental group, and the other as the comparison group.

Experiment Conducted to Collect Data

The procedure adopted for experimenting was as follows.

1. A nonverbal intelligence test (Standard Progressive Matrices) was conducted.
2. A logical mathematical intelligence test was conducted
3. Pre-test (Achievement test and Physics Attitude Scale)
4. Learning by the experimental group
5. Learning by the comparison group
6. Posttest (Achievement test and Physics Attitude Scale)

Administration of Non-Verbal Intelligence Test and Logical Mathematical Intelligence Test

After preparing the lesson plans and developing tools for study, the researcher took permission from the schools concerned to undertake experiments. One 1 hour was allotted per day, and one extra period was also given. As a first step, the investigator built a strong connection with the students, and then the nonverbal intelligence test (Standard Progressive Matrices) and the logical mathematical intelligence test were administered to both the experimental and comparison groups. Necessary instructions were provided to students before administering the test.

Administration of Pre-test

The investigator equated two groups, using the result of the nonverbal intelligence test (Standard Progressive Matrices). Then the investigator conducted a pre-test for both groups on the next day in adjacent periods. The scores obtained by the pupils were collected, scored and subjected to statistical analysis.

Learning by Comparison Group

The comparison group was handled by the investigator through problem-based learning without a concept mapping strategy. The investigator took 20 periods of one hour duration to complete the whole chapter selected.

Learning by the Experimental Group

The investigator had conducted classes on the basis of already prepared instructional materials, based on the concept mapping strategy in problem-based learning. Students were given opportunities to draw concept maps on their own. They were given with the freedom to ask questions and discuss with each other and also with the investigator. During the experimental period, the investigator acted as a facilitator of learning process.

Administration of Posttest

The posttest was conducted after the completion of the classes for both the experimental and the comparison groups.

Statistical Technique used in this Study

The pre-test and posttest answer sheets collected from the students of both the experimental and comparison groups were scored as per the priorly set guidelines and scoring keys of each test. These obtained scores were organized, and the gain in scores was computed. The gain scores were then considered as raw scores for further statistical analysis. The following major statistical techniques were employed to analyse the obtained data with the view to test the hypotheses.

Analysis of Covariance (ANCOVA)

ANCOVA is a statistical technique to compare sets of data containing one or more means by controlling the effects of one or more covariates (In this case, non-verbal intelligence and logical mathematical intelligence). This technique allows for the adjustment of the dependent variable (achievement in physics or attitude towards physics in this case) for linear effects of covariates to obtain a clear understanding of the effectiveness of the instructional strategy.

Two-Way Analysis of Variance (Two-Way ANOVA)

Two-way ANOVA is employed to understand how two independent variables (instructional strategy and logical-mathematical intelligence in this case) have effect on a dependent variable (achievement in Physics and attitude towards Physics in this case). Also, this technique tests for interaction effects that indicate whether the effect of one independent variable on the dependent variable changes across levels of the other independent variables.

These techniques will help in analysing whether the instructional strategies have a significant impact on achievement in Physics and attitude towards Physics, taking into account their levels of nonverbal and logical-mathematical intelligence.

Conclusion

The present study was experimental, where the investigator made use of a quasi-experimental pretest, posttest, comparison group design. This research study was conducted in Narokkavu Higher Secondary School, Malappuram (Dist.) XI standard students of the two classes were taken as a sample for the present study, where one division served as a comparison group and the other as an experimental group. Lesson plans and selected tools were prepared by the investigator, and classes were taken accordingly.

Techniques used and analysis of the collected data are discussed in Chapter IV.

Chapter 4

ANALYSIS AND INTERPRETATION OF DATA

ANALYSIS AND INTERPRETATION

"Without data, you're just another person with an opinion."

- Deming (1993)

The present study aims to investigate the effect of the Concept Mapping Strategy in Problem-Based Learning in Physics at the higher secondary level. The study aims to find out the main effects and interaction effects of instructional strategy and logical mathematical intelligence on Achievement and Attitude towards Physics for the total sample. The researcher implemented a pre-test for both the comparison group and experimental group. After the completion of the classes for both the experimental and the comparison groups, the posttest was conducted. The pre-test and posttest answer sheets obtained from the students of both the experimental and comparison groups were scored as per the guidelines and scoring keys of each test. These obtained scores are tabulated, and the gain in scores is computed. The gain scores were considered as raw scores for statistical analysis.

In this chapter, the investigator aims to analyse and interpret the data collected from all the tools that were administered with statistical techniques. For this, we applied t-test, ANCOVA and two-way Analysis of Variance (two-way ANOVA) to find out the main effects and interaction effects of instructional strategy and logical mathematical intelligence on achievement and attitude towards Physics.

Objectives of the Study

The main objectives of the study are,

1. To find out the effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning/Problem-Based Learning without Concept Mapping Strategy) on achievement in Physics of Higher Secondary School students.
2. To find out the effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning/Problem-Based Learning without Concept Mapping Strategy) on attitude towards Physics among Higher Secondary School students.
3. To study the main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and Logical Mathematical Intelligence on Achievement in Physics for the total sample.
4. To study the main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning /Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on Attitude towards Physics for the total sample.

Hypotheses of the Study

1. There will not be any significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) with nonverbal intelligence and logical mathematical intelligence as covariates on achievement in Physics among higher secondary school students.
2. There will not be any significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning/ Problem-Based Learning without Concept Mapping Strategy) with nonverbal intelligence and logical

mathematical intelligence as covariates on attitude towards Physics among higher secondary school students.

3. There will not be any significant main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on achievement in Physics for the total sample.
4. There will not be any significant main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning/ Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on attitude towards Physics for the total sample.

Preliminary Analysis

To find the nature of the distribution of pretest scores and posttest scores of Achievement in Physics and Attitude towards Physics, preliminary analysis was conducted and the normality of the distribution of pretest scores and posttest scores of Achievement in Physics and Attitude towards Physics for the Experimental group and Comparison group were tested. The statistical values like Mean, Median, Mode, Standard Deviation, Skewness, Kurtosis and Z-value for Skewness, Kurtosis were calculated.

The obtained statistical values of pre-test scores and posttest scores of Achievement in Physics and Attitude towards Physics for the experimental group are presented in the table 10.

Table 10

Descriptive Statistics of Pretest Scores and Posttest Scores of Achievement in Physics and Attitude towards Physics for the Experimental Group

Statistics	Pretest		Posttest	
	Achievement in Physics	Attitude towards Physics	Achievement in Physics	Attitude towards Physics
N	50	50	50	50
Mean	.92	146.14	27.32	288.66
Median	1.0	148.00	28.0	290.00
Mode	1.0	140.0	28.0	290.0
Std. Deviation	.566	7.20	1.96	4.26
Skewness	-0.03	-0.85	-0.82	-0.77
Std. Error of Skewness	0.34	0.34	0.34	0.34
Z- Z-Value (Skewness)	-0.07	-2.53	-2.44	-2.28
Kurtosis	0.26	0.85	0.29	-0.08
Std. Error of Kurtosis	0.66	0.66	0.66	0.66
Z- Z-Value (Kurtosis)	.39	1.29	.44	-.12

The table shows that the mean, median and mode of pretest achievement in physics of the experimental group are.92, 1.0 and 1.0, respectively, with a standard deviation of .566. Obtained skewness value is -0.03 and kurtosis value is 0.26, it shows that the distribution is slightly negatively skewed and leptokurtic. The z-value of skewness and kurtosis are -0.07 and 0.39 respectively. Obtained values are within the range of significance at 0.01 level, hence the pretest achievement in physics score is normally distributed.

Mean, median and mode of pretest attitude towards physics of experimental group are 146.14, 148 and 140, respectively, with a standard deviation of 7.20. Obtained skewness value is -0.85 and kurtosis value is 0.85, it shows that the distribution is slightly negatively skewed and leptokurtic. The z-value of skewness and kurtosis are -2.53 and 1.29 respectively. Obtained values are within the range of significance at 0.01 level, hence the pretest attitude towards physics score is normally distributed.

Mean, median and mode of posttest achievement in physics of the experimental group are 27.32, 28 and 28, respectively, with a standard deviation of 1.96. Obtained skewness value is -0.82 and kurtosis value is 0.29, it shows that the distribution is slightly negatively skewed and leptokurtic. The z-value of skewness and kurtosis are -2.44 and 0.44 respectively. Obtained values are within the range of significance at 0.01 level, hence the posttest achievement in physics score is normally distributed.

Mean, median and mode of posttest attitude towards physics of experimental group are 288.66, 290 and 290, respectively, with a standard deviation of 4.26. Obtained skewness value is -0.77 and kurtosis value is -0.08, it shows that the distribution is slightly negatively skewed and platykurtic. The z-value of skewness and kurtosis are -2.28 and -0.12 respectively. obtained values are within the range of significance at 0.01 level, hence the posttest attitude towards physics score is normally distributed.

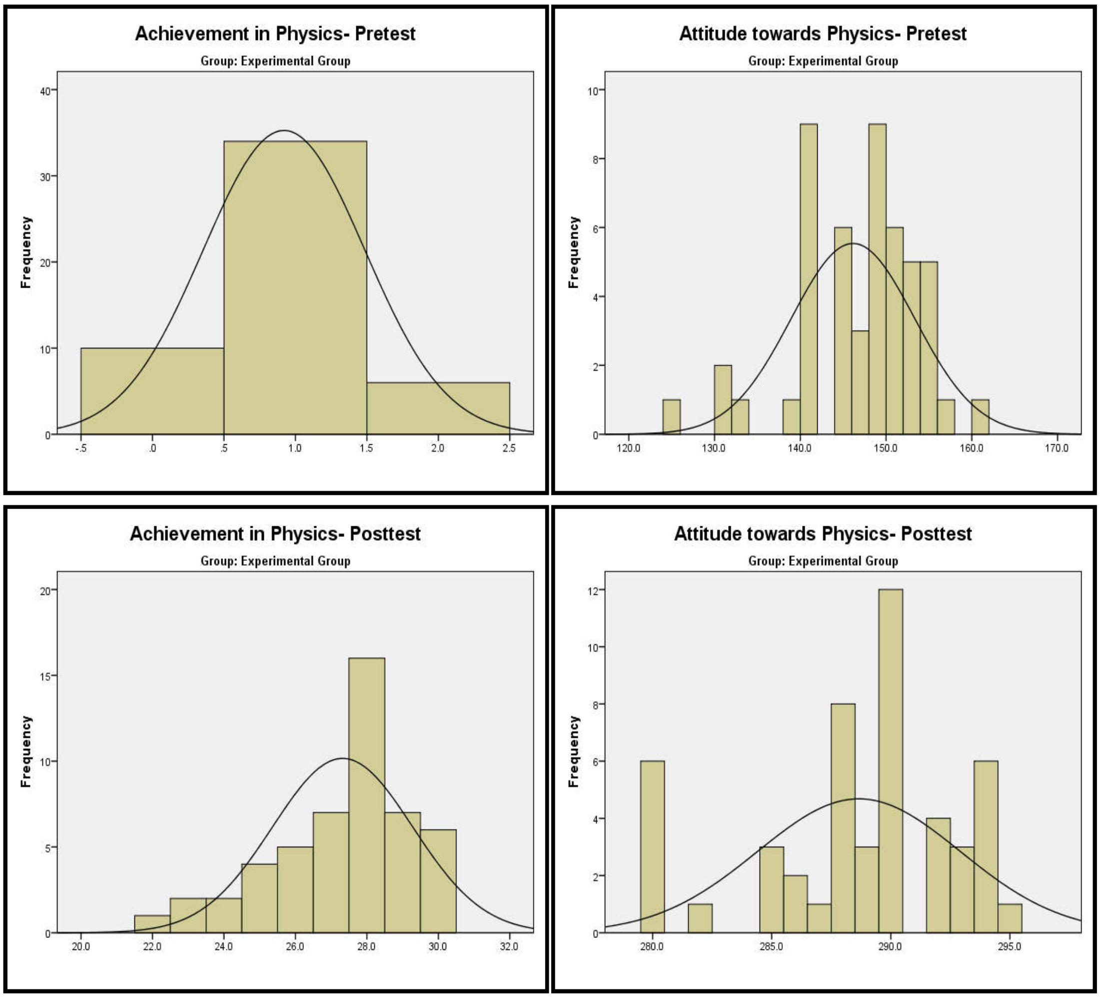
Conclusion

From the results of the table 10, it can be concluded that pretest achievement in physics score, pretest attitude towards physics score, posttest achievement in physics score and posttest attitude towards physics score of experimental groups are normally distributed.

The histograms with normal curves were drawn for pretest scores and posttest scores of Achievement in Physics and Attitude towards Physics for the experimental group and are presented as a figure 9.

Figure 9

The Histogram with Normal Curve for Pretest Score and Posttest Scores of Achievement in Physics and Attitude towards Physics for the Experimental Group



Visual inspection of the histogram with the normal curve also showed that pretest and posttest scores of Achievement in Physics and Attitude towards Physics for the experimental group are normally distributed.

The obtained statistical values of pretest scores and posttest scores of Achievement in Physics and Attitude towards Physics for the comparison group are presented in the table 11.

Table 11

Descriptive Statistics of Pretest Scores and Posttest Scores of Achievement in Physics and Attitude towards Physics for the Comparison Group

Statistics	Pretest		Posttest	
	Achievement in Physics	Attitude towards Physics	Achievement in Physics	Attitude towards Physics
N	50	50	50	50
Mean	.92	147.54	20.60	269.26
Median	1.0	148.00	20.00	270.00
Mode	1.0	140.0	20.0	270.0
Std. Deviation	.57	7.98	1.98	5.12
Skewness	-0.02	-0.18	0.17	-0.30
Std. Error of Skewness	0.34	0.34	0.34	0.34
Z-Value (Skewness)	-0.07	-0.55	0.52	-0.88
Kurtosis	0.26	-0.84	0.714	-0.09
Std. Error of Kurtosis	0.66	0.66	0.66	0.66
Z-Value (Kurtosis)	0.39	-1.22	1.08	-0.13

The table shows that the mean, median and mode of pretest achievement in physics of the comparison group are.92, 1.0 and 1.0, respectively with a standard deviation of .57. Obtained skewness value is -0.02 and kurtosis value is 0.26, it shows that the distribution is slightly negatively skewed and leptokurtic. The z-value of skewness and kurtosis are -0.07 and 0.39 respectively. Obtained values are within the range of significance at 0.01 level, hence the pretest achievement in physics score is normally distributed.

Mean, median and mode of pretest attitude towards physics of the comparison group are 147.54, 148 and 140, respectively, with a standard deviation of 7.98. Obtained skewness value is -0.18 and kurtosis value is -0.84, it shows that the distribution is slightly negatively skewed and platykurtic. The z-value of skewness and kurtosis are -0.55 and -1.22 respectively. Obtained values are within the range of significance at 0.01 level, hence the pretest attitude towards physics score is normally distributed.

Mean, median and mode of posttest achievement in physics of the comparison group are 20.60, 20 and 20, respectively, with a standard deviation of 1.98. Obtained skewness value is 0.17 and kurtosis value is 0.71, it shows that the distribution is slightly positively skewed and leptokurtic. The z-value of skewness and kurtosis are 0.52 and 1.08 respectively. Obtained values are within the range of significance at 0.01 level, hence the posttest achievement in physics score is normally distributed.

Mean, median and mode of posttest attitude towards physics of the comparison group are 269.26, 270 and 270, respectively, with a standard deviation of 5.12. Obtained skewness value is -0.88 and kurtosis value is -0.09, it shows that the distribution is slightly negatively skewed and platykurtic. The z-value of skewness and kurtosis are -0.88 and -0.13 respectively. Obtained values are within the range of significance at 0.01 level, hence the posttest attitude towards physics score is normally distributed.

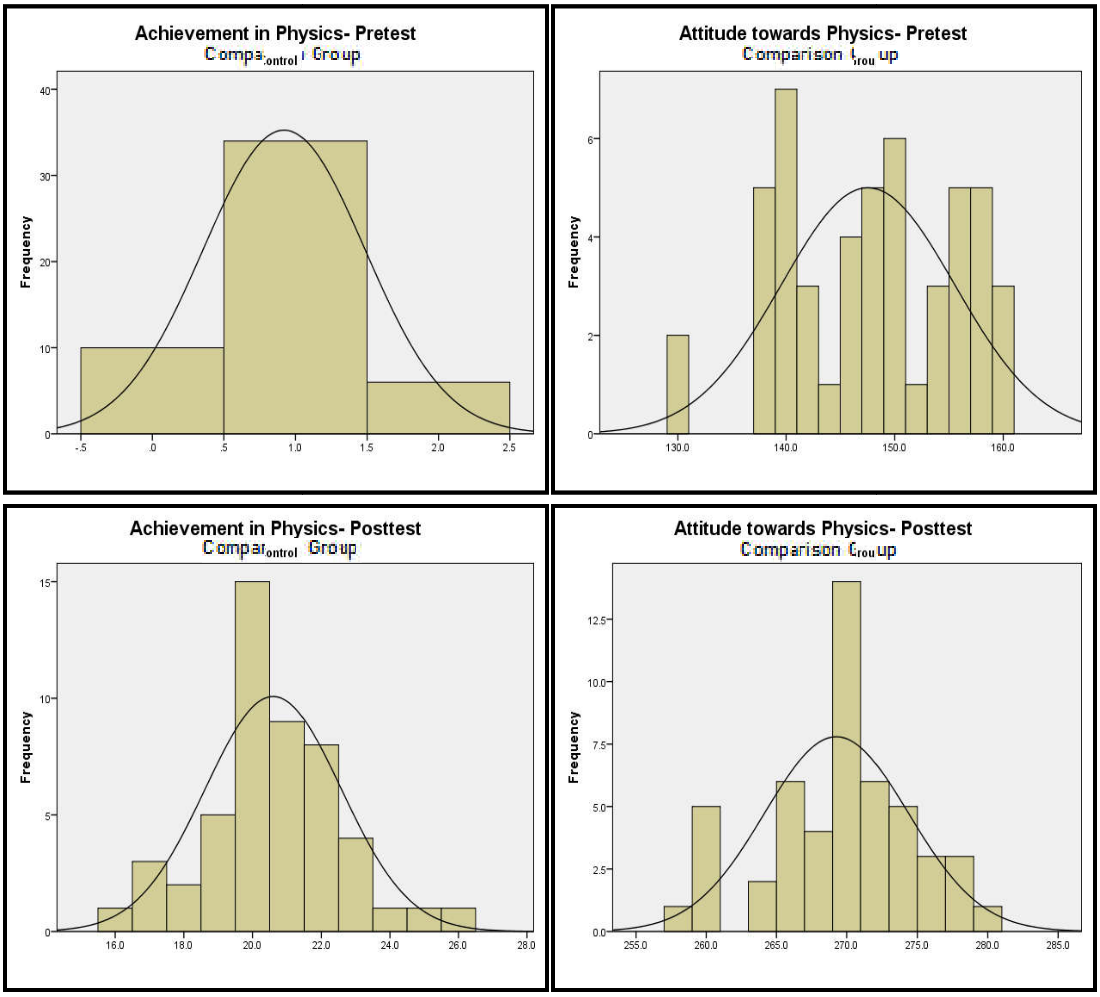
Conclusion

From the results of the table 11 it can be concluded that pretest achievement in physics score, pretest attitude towards physics score, posttest achievement in physics score and posttest attitude towards physics score of comparison groups are normally distributed.

The histograms with normal curve were drawn for pretest scores and posttest scores of Achievement in Physics and Attitude towards Physics for the comparison group and are presented as a figure 10

Figure 10

The Histogram with Normal Curve for Pretest Scores and Posttest Scores of Achievement in Physics and Attitude towards Physics for the Comparison Group



Effectiveness of Concept Mapping Strategy in Problem-Based Learning on Achievement in Physics and Attitude towards Physics of Higher Secondary School Students

The major objective of this study is to find out the effectiveness of the Concept Mapping Strategy in Problem-Based Learning on Achievement in Physics and Attitude towards Physics of higher secondary school students. For this purpose investigator used the independent sample t test, paired sample t test and Analysis of covariance (ANCOVA). In this section, the investigator compared the groups with respect to academic achievement at pre-test, posttest and gain score. Details of the analysis are presented under the following headings.

- Comparison of Achievement in Physics and Attitude towards Physics between Experimental and Comparison Groups before intervention
- Comparison of Achievement in Physics and Attitude towards Physics between Experimental and Comparison Groups after Intervention
- Comparison of mean scores of pretest and posttest on Achievement in Physics and Attitude towards Physics of the experimental group
- Comparison of mean scores of pretest and posttest on Achievement in Physics and Attitude towards Physics of the Comparison group
- Comparison of mean gain scores on Achievement in Physics and Attitude towards Physics of experimental and Comparison Groups
- Comparison of mean gain scores on Achievement in Physics of experimental and Comparison Groups with Nonverbal Intelligence and Logical Mathematical Intelligence scores as covariates
- Comparison of mean gain scores on Attitude towards Physics of experimental and Comparison group with Nonverbal Intelligence and Logical Mathematical Intelligence score as covariates

Comparison of Achievement in Physics and Attitude towards Physics between Experimental and Comparison Groups before Intervention

To test the Achievement in Physics and Attitude towards Physics between the experimental and comparison groups before intervention, independent sample t-test was done to find the significant difference between mean pretest scores of Achievement in Physics and Attitude towards Physics.

Results of the mean score comparison of pretest scores in Achievement in Physics and Attitude towards Physics are shown in the table 12 below.

Table 12

Comparison of the Mean Pretest Score of Achievement in Physics and Attitude towards Physics between Experimental and Comparison Groups

Variable	Group	N	Mean	Std. Deviation	t-value
Achievement in Physics	Experimental Group	50	.92	.57	0
	Comparison Group	50	.92	.57	
Attitude towards Physics	Experimental Group	50	146.14	7.20	.921
	Comparison Group	50	147.54	7.98	

The table shows that, before intervention, there is no significant difference between the mean score of Achievement in Physics of the Experimental group (M= 0.92, SD = 0.57) and Comparison group (M= 0.92, SD = 0.57) [t = 0; p >.05]. Hence, before intervention, the experimental group and comparison group are equal in Achievement in Physics.

The table also revealed that, before intervention, there is no significant difference between the mean score of Attitude towards Physics of the Experimental group (M= 146.14, SD = 7.20) and Comparison group (M= 147.54, SD = 7.98) [t = .921; p >.05]. Hence, before intervention, the experimental group and comparison group are equal in Attitude towards Physics.

Conclusion

From table 12, it can be concluded that before intervention, the experimental group and comparison group are equal in Achievement in Physics and attitude towards physics.

Graphical representation of comparison of mean pretest scores of Achievement in Physics and Attitude towards Physics for experimental and comparison groups is presented in Figure 11 and Figure 12 respectively.

Figure 11

Graphical Representation of the Comparison of the Mean Pretest Score of Achievement in Physics for the Experimental and Comparison Groups

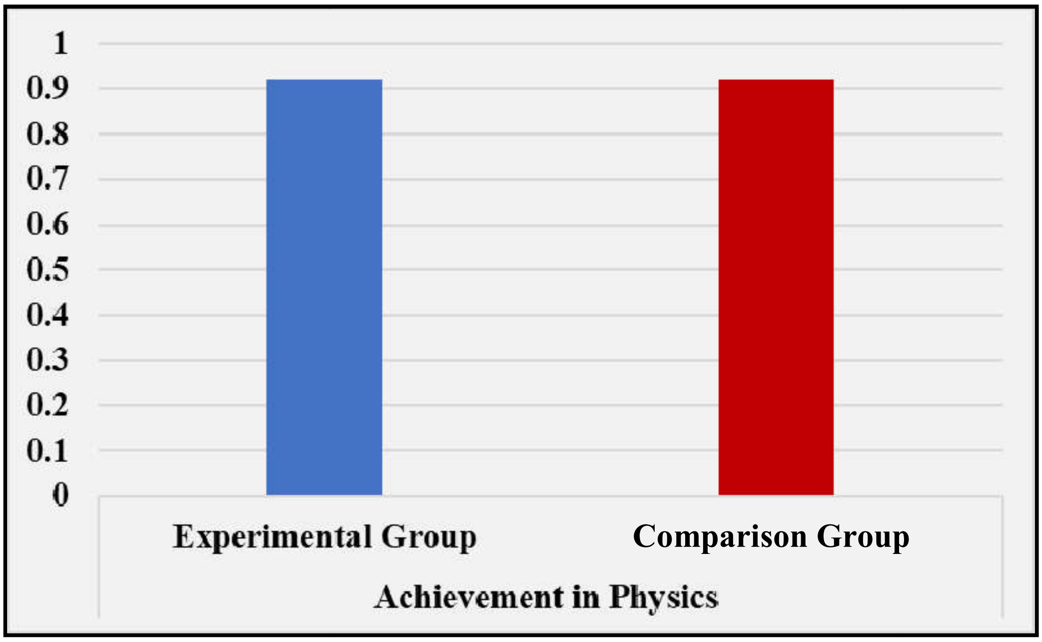
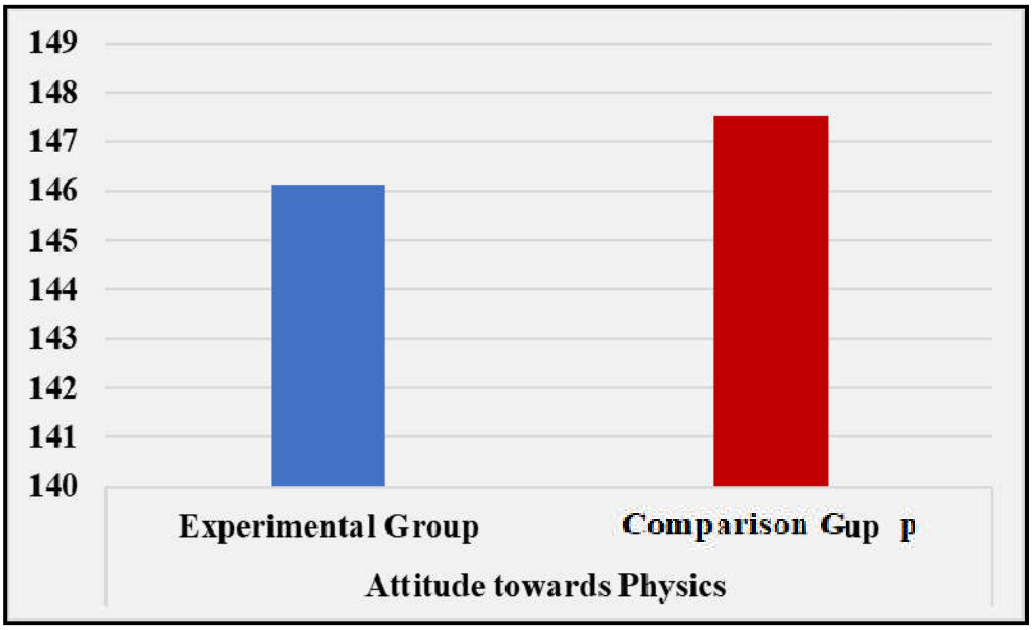


Figure 12

Graphical Representation of the Comparison of the Mean Pretest Score of Attitude towards Physics for the Experimental and Comparison Groups



Comparison of Achievement in Physics and Attitude towards Physics between Experimental and Comparison Groups after Intervention

To test the Achievement in Physics and Attitude Towards Physics between the experimental and comparison groups after intervention, independent sample t-test was done to find the significant difference between mean pretest scores of Achievement in Physics and Attitude Towards Physics was done.

Results of the mean score comparison of posttest scores in Achievement in Physics and Attitude towards Physics are shown in the table 13 below.

Table 13

Comparison of the Mean Posttest Score of Achievement in Physics and Attitude towards Physics between Experimental and Comparison Groups

Variable	Group	N	Mean	Std. Deviation	t-value
Achievement in Physics	Experimental Group	50	27.32	1.96	17.04**
	Comparison Group	50	20.60	1.98	
Attitude towards Physics	Experimental Group	50	288.66	4.26	20.60**
	Comparison Group	50	269.26	5.12	

**Significant at 0.01 level

The table shows that, after the intervention of the concept mapping strategy in Problem-Based Learning, there is a significant difference in the mean scores of achievement in physics of the experimental group (*M* = 27.32, *SD* = 1.96) and comparison group (*M* = 20.60, *SD* = 1.98) [$t = 17.04$; $p<0.01$]. The mean score of achievement in physics of the experimental group is higher than achievement in physics of the comparison group. That is in the posttest, students treated with the concept mapping strategy in Problem-Based Learning had a higher score in achievement in Physics.

The table also shows that, after the intervention of the Concept Mapping strategy in Problem Based Learning, there is a significant difference in the mean scores of attitude towards physics of the experimental group (*M*= 288.66, *SD* =4.26) and comparison group (*M*=269.26, *SD*=5.12) [*t*=20.60; *p*<0.01]. The mean score of attitude towards physics of the experimental group is higher than attitude towards physics of the comparison group. That is in the posttest, students treated with the concept mapping strategy in problem-based learning had a higher score in attitude towards physics.

Conclusion

From table 13, it can be concluded that there exist a significant difference in the posttest scores of achievement in physics and attitude towards physics of experimental group and comparison group. Students treated with the concept mapping strategy in problem-based learning had a higher score in both achievement in physics and attitude towards physics.

Graphical representation of comparison of mean posttest scores of Achievement in Physics and Attitude towards Physics for experimental and comparison groups is presented below.

Figure 13

Graphical Representation of the Comparison of the Mean Posttest Score of Achievement in Physics for the Experimental and Comparison Groups

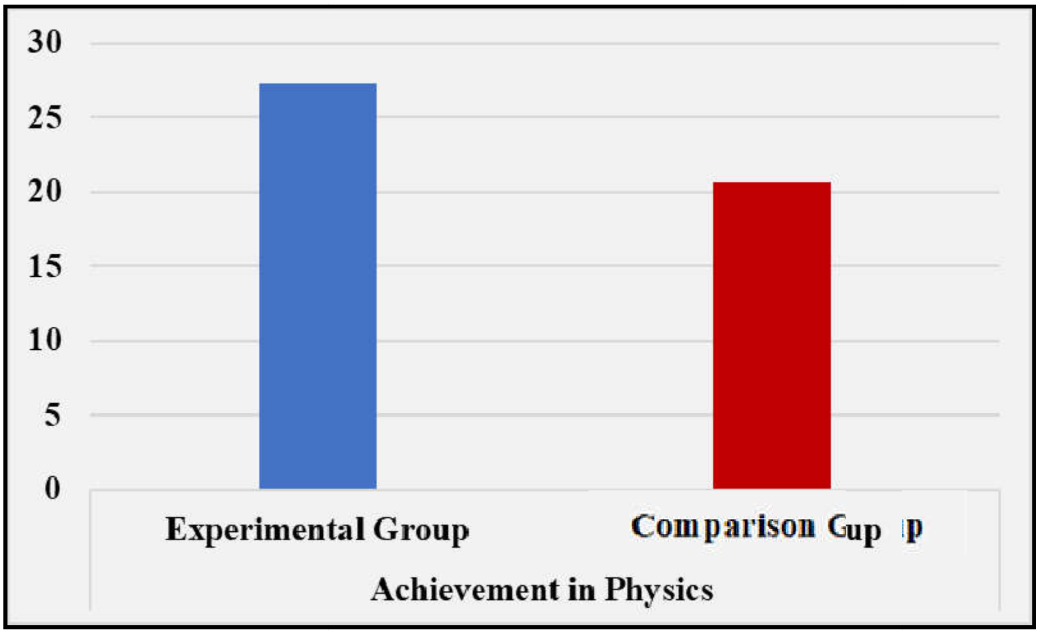
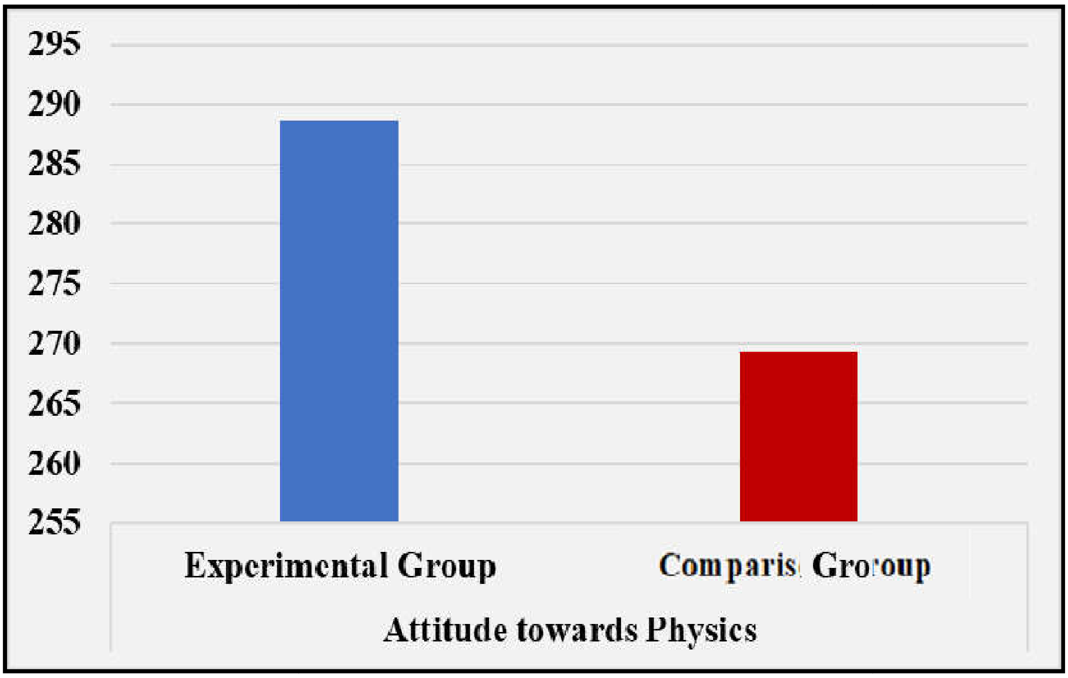


Figure 14

Graphical Representation of the Comparison of the Mean Posttest Score of Attitude towards Physics for the Experimental and Comparison Groups



Comparison of Mean Scores of Pretest and Posttest on Achievement in Physics and Attitude towards Physics of the Experimental Group

To find out the effectiveness of Concept Mapping Strategy in Problem-Based Learning on Achievement in Physics and Attitude towards Physics of higher secondary school students, mean pretest and posttest scores of the experimental group were compared by using paired sample t-test.

The results of the paired sample t-test between mean pretest and posttest scores of Achievement in Physics and Attitude towards Physics of the experimental group are presented in the table 14 below.

Table 14

Comparison of Mean Scores of Achievement in Physics and Attitude towards Physics in Pretest and Posttest Scores of Experimental Group

Variable	Test	Mean	N	Std. Deviation	r-value	t-value
Achievement in Physics	Posttest	27.32	50	1.96	.81	121.32**
	Pretest	.920	50	.566		
Attitude towards Physics	Posttest	288.66	50	4.26	.31	141.47**
	Pretest	146.14	50	7.20		

**Significant at 0.01 level

The table shows that, for the experimental group, there is a significant difference in the mean posttest scores (*M*= 27.32, *SD* =1.96) and pretest scores (*M*= .920, *SD* = 0.57) [t = 121.32; p<0.01] of Achievement in Physics. The mean posttest score of Achievement in Physics of the experimental group is higher than the mean pretest score of Achievement in Physics. That is in the experimental group, scores in Achievement in Physics are higher after the treatment of the concept mapping strategy in problem-based learning. It shows that the concept mapping strategy in problem-based learning has a significant effect on Achievement in Physics of higher secondary school students.

The table shows that, for the experimental group, there is a significant difference in the mean posttest scores (*M*= 288.66, *SD* =4.26) and pretest scores (*M*= 146.14, *SD* = 7.20) [t = 141.47; p<0.01] of Attitude towards Physics. The mean posttest score of Attitude towards Physics of the experimental group is higher than the mean pre-test score of Attitude towards Physics. That is, in the experimental group, scores in Attitude towards Physics are higher after the treatment of the concept mapping strategy in problem-based learning. It shows that the concept mapping strategy in problem-based learning has a significant effect on the Attitude towards Physics of higher secondary school students.

Conclusion

From table 14, it can be concluded that there exist a significant difference in the pretest and posttest scores of achievement in physics and attitude towards physics of experimental group. It shows that the concept mapping strategy in problem-based learning has a significant effect on both achievement in physics attitude towards physics of higher secondary school students.

Comparison of Mean Scores of Pretest and Posttest on Achievement in Physics and Attitude towards Physics of the Comparison Group

To find out the effectiveness of Concept Mapping Strategy in Problem-Based Learning on Achievement in Physics and Attitude towards Physics of higher secondary school students, the mean pretest and posttest scores of the experimental group were compared by using paired sample t-test.

The results of the of the paired sample t-test test of the significance of the difference between mean pretest and posttest scores of Achievement in Physics and Attitude towards Physics of the comparison group are presented in the table 15 below.

Table 15

Comparison of Mean Scores of Achievement in Physics and Attitude towards Physics in Pretest and Posttest Scores of Comparison Group

Variable	Test	Mean	N	Std. Deviation	r-value	t-value
Achievement in Physics	Posttest	20.60	50	1.98	.70	85.15**
	Pretest	.920	50	.56		
Attitude towards Physics	Posttest	269.26	50	5.12	.38	112.30**
	Pretest	147.54	50	7.98		

The table shows that, for the comparison group, there is a significant difference in the mean posttest scores (*M*= 20.60, *SD* =1.98) and pretest scores (*M*= .920, *SD* = 0.56) [t = 85.15; p<0.01] of Achievement in Physics. The mean posttest score of Achievement in Physics of the comparison group is higher than the mean pretest scores of Achievement in Physics. There is a significant difference in the mean posttest scores (*M*= 269.26, *SD* =5.12) and pretest scores (*M*= 147.54, *SD* = 7.98) [t = 112.30; p<0.01] of Attitude towards Physics. The mean posttest score of the Attitude towards Physics of the comparison group is higher than the mean pre-test score of Attitude towards Physics.

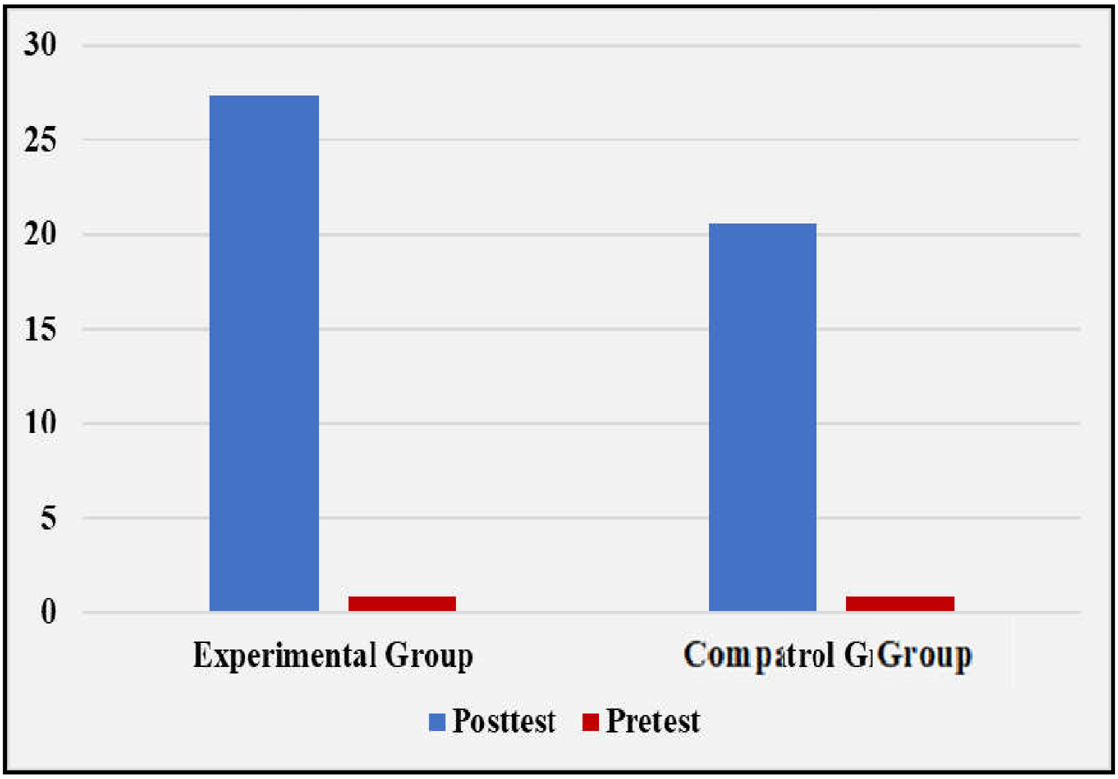
Conclusion

From table 15, it can be concluded that there exist a significant difference in the pretest and posttest scores of achievement in physics and attitude towards physics of comparison group. The mean posttest scores of the achievement in physics and attitude towards physics of the comparison group is higher than the mean pre-test scores.

Graphical representation of the comparison of mean pretest and posttest scores of Achievement in Physics of higher secondary school students for the Experimental and Comparison group is presented in the figure 15

Figure 15

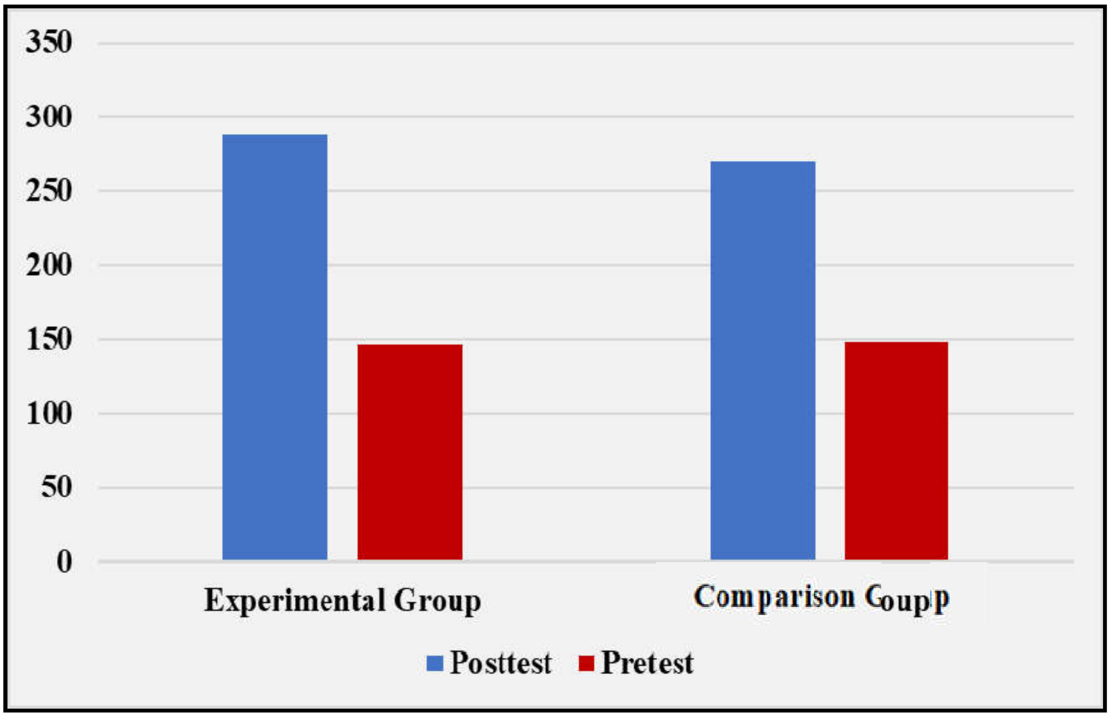
Graphical Representation of Comparison of Mean Pretest and Posttest Scores of Achievement in Physics of Higher Secondary School Students for Experimental and Comparison Groups



Graphical representation of the comparison of mean pretest and posttest scores of Attitude towards Physics of Higher Secondary School students for Experimental and Comparison groups is presented in the figure 16

Figure 16

Graphical Representation of Comparison of Mean Pretest and Posttest Scores of Attitude in Physics of Higher Secondary School Students for Experimental and Comparison Groups



Comparison of Mean Gain Scores on Achievement in Physics and Attitude towards Physics of Experimental and Comparison Groups

To find the significant difference in the mean gain scores of Achievement in Physics and Attitude towards Physics of Experimental and Comparison group. independent sample t-test was conducted.

The data and results of the comparison of the mean gain score of Achievement in Physics and Attitude towards Physics of experimental and comparison groups are presented in the table 16 below.

Table 16

Comparison of the Mean Gain Score of Achievement in Physics and Attitude towards Physics of Experimental and Comparison Groups

Variable	Group	N	Mean	Std. Deviation	t-value
Achievement in Physics Gain score	Experimental Group	50	26.40	1.54	21.17**
	Comparison Group	50	19.68	1.63	
Attitude towards Physics Gain score	Experimental Group	50	142.52	7.12	13.68**
	Comparison Group	50	122.12	7.77	

**Significant at 0.01 level

The table shows that there is a significant difference in the mean gain scores of Achievement in Physics of the experimental group (*M*= 26.40, *SD* =1.54) and comparison group (*M*= 19.68, *SD* = 1.63) [t = 21.17; p<0.01]. The mean gain score of Achievement in Physics of the experimental group is higher than the gain score of Achievement in Physics of the comparison group. That is in the gain score, students treated with the concept mapping strategy in Problem-Based Learning have a higher score in achievement in Physics. It shows that there is a significant effect of concept mapping strategy in Problem-Based Learning on Achievement in physics.

The table also shows that there is a significant difference in the mean gain scores of Attitude towards Physics of the experimental group (*M*= 142.52, *SD* =7.12) and comparison group (*M*= 122.12, *SD* = 7.77) [t = 13.68; p<0.01]. The mean gain score of Attitude towards Physics of the experimental group is higher than the gain score of Attitude towards Physics of the comparison group. That is in the gain score, students treated with the Concept Mapping strategy in Problem-Based Learning have a higher score in attitude towards physics. It shows that there is a significant effect of concept mapping strategy in Problem-Based Learning on Attitude towards Physics.

Conclusion

From table 16, it can be concluded that there exist a significant difference in the mean gin scores of achievement in physics and attitude towards physics of experimental and comparison group. Students treated with the concept mapping strategy in Problem-Based Learning have a higher score in both gain achievement in Physics and gain attitude towards Physics scores.

Graphical representation of comparison of mean gain scores of Achievement in Physics and Attitude towards Physics for experimental and comparison groups are presented in figures 17 and 18 below.

Figure 17

Graphical Representation of the Comparison of the Mean Gain Score of Achievement in Physics for Experimental and Comparison Groups

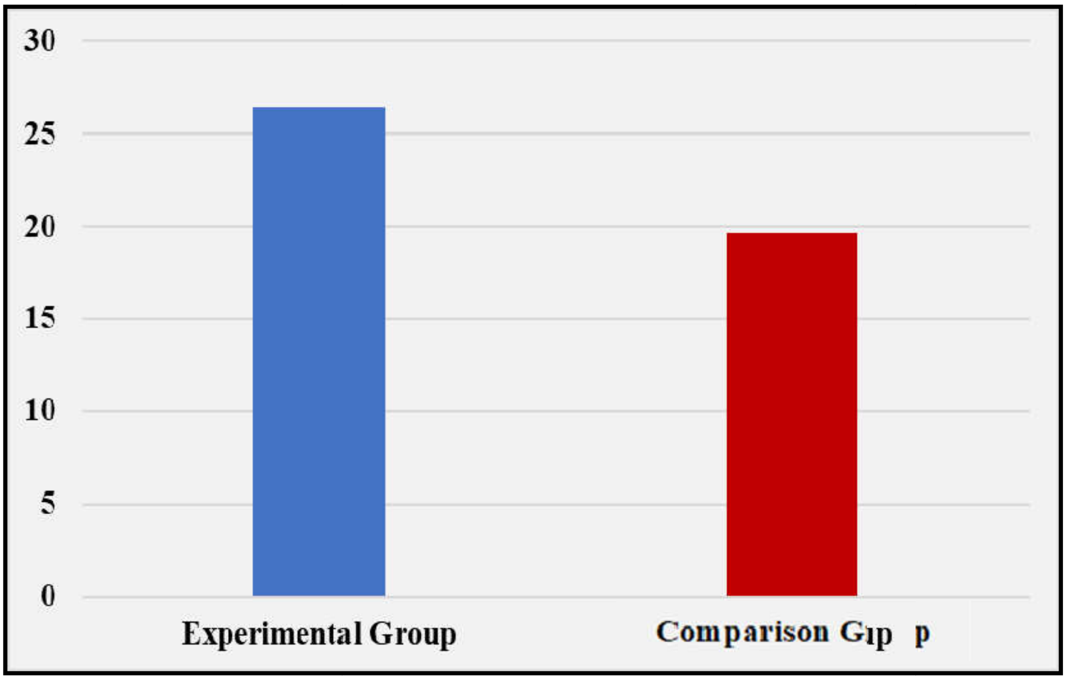
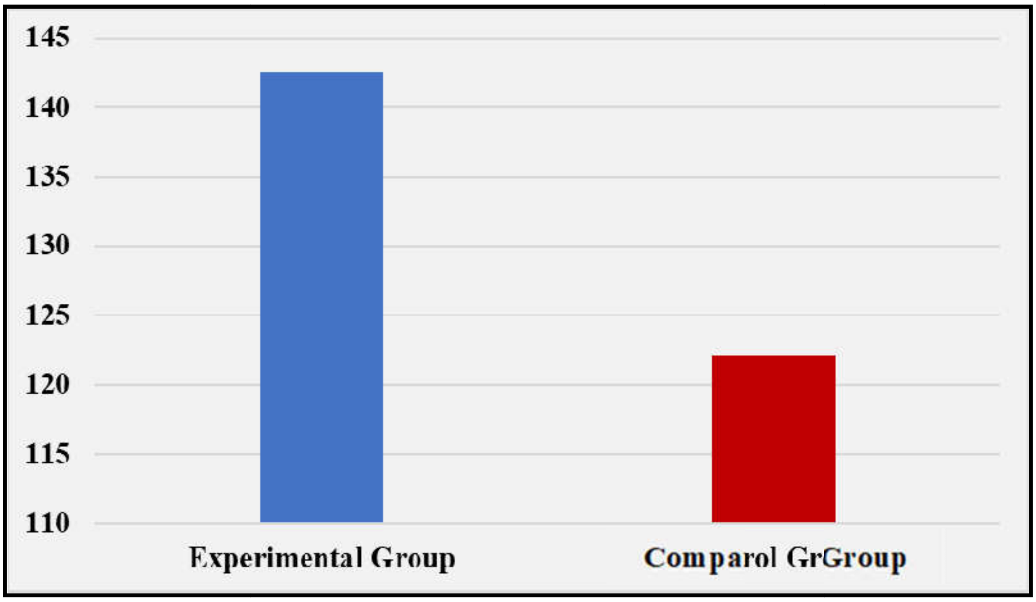


Figure 18

Graphical Representation of the Comparison of the Mean Gain Score of Attitude towards Physics for the Experimental and Comparison Groups



Comparison of Mean Gain Scores on Achievement in Physics and Attitude towards Physics of Experimental and Comparison Group with Nonverbal Intelligence and Logical Mathematical Intelligence Score as Covariates

To find the effectiveness of concept mapping strategy in problem based learning on enhancing achievement in physics and attitude towards physics, the investigator conducted ANCOVA with nonverbal intelligence and logical mathematical intelligence score as covariates.

The details of the ANCOVA conducted for the total gain score of achievement in physics with nonverbal intelligence and logical mathematical intelligence score as covariates are given in the table 17 below.

Table 17

Summary of ANCOVA of Gain Score on Achievement in Physics with Nonverbal Intelligence and Logical Mathematical Intelligence Score as Covariates

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1232.423	3	410.81	274.99	.001
Intercept	2475.69	1	2475.69	1657.20	.001
Nonverbal Intelligence	.436	1	.436	.292	.590
Logical Mathematical Intelligence	35.39	1	35.39	23.69	.001
Group	856.46	1	856.46	573.31	.001
Error	143.41	96	1.494		
Total	54460.00	100			
Corrected Total	1375.84	99			

After performing ANCOVA and the results signify that, after adjusting for Nonverbal Intelligence and Logical Mathematical Intelligence scores, there is a statistically significant difference between the experimental and comparison groups in their gain in achievement in physics, F (1,99) = 573.31, p <0.01. Hence experiment has a significant effect on the gain score on Achievement in Physics. It shows that there is a significant effect of concept mapping strategy in problem-based learning on Achievement in Physics.

The estimated marginal mean of gain in Achievement in Physics of experimental and comparison groups is presented in the table 18 below.

Table 18

Data and Results of the Comparison of the Estimated Marginal Mean of Gain Achievement in Physics of Experimental and Comparison Groups

Dependent Variable	Estimated Marginal Mean	
	Comparison Group	Experimental Group
Gains Score of Achievement in Physics	19.98	26.10

Both the observed and estimated marginal mean show that students taught through the concept mapping strategy in problem-based learning achieved better when compared to the students without being taught without the concept mapping strategy in problem-based Based Learning. It implied that the concept mapping strategy in Problem-Based Learning is better than without the concept mapping strategy in Problem-Based Learning for enhancing achievement in physics.

Conclusion

From analysis, it can be concluded that there exist a significant difference in the mean gin scores of achievement in physics of experimental and comparison group after controlling nonverbal intelligence and logical mathematical intelligence. Concept mapping strategy in Problem-Based Learning is better than without the concept mapping strategy in Problem-Based Learning for enhancing achievement in physics.

The details of the ANCOVA conducted for the total gain score of Attitude towards physics with nonverbal intelligence and logical mathematical intelligence score as covariates are given in the table 19 below.

Table 19

Summary of ANCOVA of Gain Score on Attitude towards Physics with Nonverbal Intelligence and Logical Mathematical Intelligence Score as Covariates

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	10677.69	3	3559.23	66.04	.001
Intercept	107692.26	1	107692.26	1998.13	.001
Nonverbal Intelligence	69.93	1	69.93	1.29	.258
Logical Mathematical Intelligence	215.06	1	215.06	3.99	.049
Group	8621.88	1	8621.88	159.97	.001
Error	5174.07	96	53.89		
Total	1766710.00	100			
Corrected Total	15851.76	99			

After performing ANCOVA and the results signify that, after adjusting for Nonverbal Intelligence and Logical Mathematical Intelligence scores, there is a statistically significant difference between the experimental and comparison groups in their gain in Attitude towards Physics, F (1,99) = 159.97, p <0.01. Hence experiment has a significant effect on the gain score on Attitude towards Physics. It shows that there is a significant effect of concept mapping strategy in Problem-Based Learning on Attitude towards Physics.

The estimated marginal mean of gain Attitude towards Physics of experimental and comparison groups are presented in the table 20 below.

Table 20

Data and Results of the Comparison of the Estimated Marginal Mean of Gain, Attitude towards Physics of Experimental and Comparison Groups

Dependent Variable	Estimated Marginal Mean	
	Comparison Group	Experimental Group
Gains score of Attitude towards Physics	122.61	142.03

Both the observed and estimated marginal mean show that students taught through the concept mapping strategy in Problem-Based Learning achieved better when compared to the students without being taught without the Concept mapping strategy in Problem-Based Learning. It implied that the Concept Mapping Strategy in Problem-Based Learning is better than the present method of teaching for enhancing attitude towards physics.

Conclusion

From analysis, it can be concluded that there exist a significant difference in the mean gin scores of attitude towards physics of experimental and comparison group after controlling nonverbal intelligence and logical mathematical intelligence. Concept mapping strategy in Problem-Based Learning is better than without the concept mapping strategy in Problem-Based Learning for enhancing attitude towards physics.

Main Effects and Interaction Effects of Instructional Strategy and Logical Mathematical Intelligence on Achievement in Physics

One of the objectives of the study is to main and interaction effects of Concept Mapping Strategy in Problem-Based Learning and Logical Mathematical Intelligence on Achievement in Physics. For this two-way ANOVA with a 2x3 factorial design was used. The teaching strategy group was categorised into two groups: students treated with the Concept Mapping Strategy in Problem-Based Learning and students treated without the Concept Mapping Strategy in Problem-Based Learning. Logical mathematical Intelligence was grouped into three categories: Low Logical Mathematical Intelligence, Average Logical Mathematical Intelligence, and High Logical Mathematical Intelligence.

Data and results of the analysis of the main and interaction effects of instructional strategy and Logical Mathematical Intelligence on Achievement in Physics are presented in the table 21 below.

Table 21

Summary of 2 x 3 Factorial ANOVA of Instructional Strategy and Logical Mathematical Intelligence on Achievement in Physics

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1308.59	5	261.72	122.24	.001
Intercept	34386.62	1	34386.62	16061.01	.001
Group	599.85	1	599.85	280.17	.001
Logical Mathematical Intelligence Group	171.42	2	85.71	40.03	.001
Group * Logical Mathematical Intelligence Group	.832	2	.416	.194	.824
Error	201.25	94	2.14		
Total	58918.00	100			
Corrected Total	1509.84	99			

The two-way ANOVA revealed there is no significant interaction effect between instructional strategy and Logical Mathematical Intelligence on Achievement in Physics (F (2,94) = .194, $p > 0.05$). This indicates that there is no significant effect of Logical Mathematical Intelligence on the effect of instructional strategy on Achievement in Physics.

Main effect analysis shows that there exist significant main effects for instructional strategy (F (1, 94) = 280.17, $p < .001$) and Logical Mathematical Intelligence (F (2,94) = 40.03, $p < .01$) on the Achievement in Physics. This indicates that both instructional strategy and Logical Mathematical Intelligence have individual effects on the Achievement in Physics.

To assess the differences between groups in Logical Mathematical Intelligence, Scheffé's post hoc test for comparisons was employed. The corresponding results are presented in table 22 below.

Table 22

Scheffé's Post-hoc Test for Comparisons for Logical Mathematical Intelligence

Group		Mean Difference	Std. Error	Sig.
Low Logical Mathematical Intelligence (M =20.87)	Average Logical Mathematical Intelligence (*M*=23.80)	2.93	.407	.001
Low Logical Mathematical Intelligence	High Logical Mathematical Intelligence (*M*= 27.28)	6.40	.502	.001
Average Logical Mathematical Intelligence	High Logical Mathematical Intelligence	3.47	.389	.001

The mean difference between the low Logical Mathematical Intelligence group (M = 20.87) and the average Logical Mathematical Intelligence group (M = 23.80) is 2.93. The standard error is 0.407, and the p-value is 0.001 (indicating statistical significance). Therefore, the mean Achievement in Physics score of the average group is significantly higher than that of the low group. The mean difference between the low Logical Mathematical Intelligence (M = 20.87) and the high Logical Mathematical Intelligence (M = 27.28) is 6.40. The standard error is 0.502, and the p-value is 0.001 (indicating statistical significance). This suggests that the mean Achievement in Physics score of the high group is significantly higher than that of the low group. The mean difference between the average Logical Mathematical Intelligence (M = 23.80) and the high Logical Mathematical Intelligence (M = 27.28) is 3.47. The standard error is 0.389, and the p-value is 0.001 (indicating statistical significance). Therefore, the mean Achievement in Physics score of the high group is significantly higher than that of the average group.

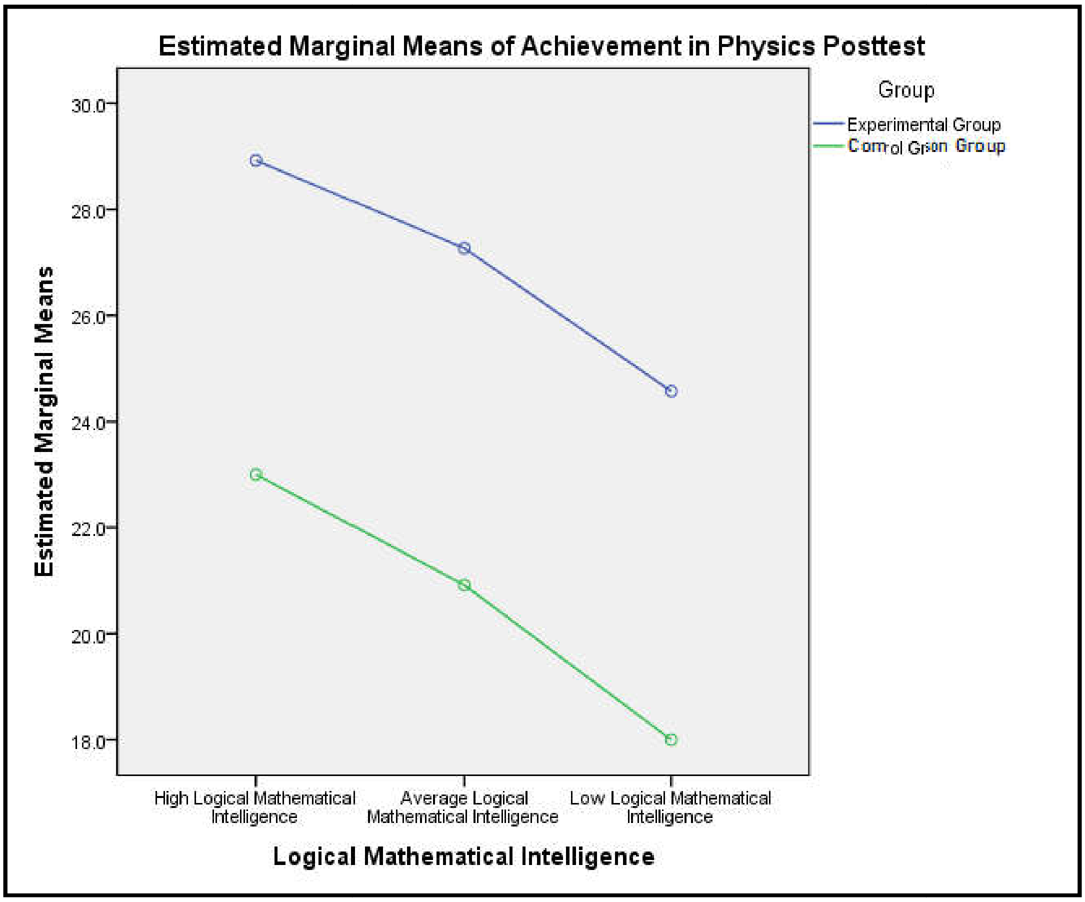
Conclusion

The two-way ANOVA analysis shows that there is no significant interaction effect between instructional strategy and Logical Mathematical Intelligence on Achievement in Physics

A graphical representation of the interaction effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and Logical Mathematical Intelligence on Achievement in Physics is presented in the figure 19 below.

Figure 19

Graphical Representation of the Interaction Effect of Instructional Strategy and Logical Mathematical Intelligence on Achievement in Physics



Main Effects and Interaction Effects of Instructional Strategy and Logical Mathematical Intelligence on Attitude towards Physics

Data and results of analysis of main and interaction effects of instructional strategy and Logical Mathematical Intelligence on Attitude towards Physics is presented in the table 23 below.

Table 23

Summary of 2 × 3 Factorial ANOVA of Instructional Strategy and Logical Mathematical Intelligence on Attitude towards Physics

Source	Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	9871.30	5	1974.26	108.49	.001
Intercept	4716873.71	1	4716873.71	259208.48	.001
Group	5162.15	1	5162.15	283.68	.001
Logical Mathematical Intelligence Group	455.58	2	227.79	12.52	.001
Group * Logical Mathematical Intelligence Group	7.24	2	3.62	.199	.820
Error	1710.54	94	18.19		
Total	7793450.00	100			
Corrected Total	11581.84	99			

The two-way ANOVA revealed there is no significant interaction effect of instructional strategy and Logical Mathematical Intelligence on Attitude towards Physics (F (2,94) = .199, p > 0.05). This indicates that there is no significant effect of Logical Mathematical Intelligence on the effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning/Problem-Based Learning without Concept Mapping Strategy), on varies depending on Attitude towards Physics.

Main effect analysis shows that there exist significant main effects of instructional Strategy (F (1, 94) = 283.68, $p < .001$) and logical-mathematical intelligence (F (2, 94) = 12.52, $p < .01$) on the Attitude towards Physics. This indicates that both Concept Mapping Strategy in Problem-Based Learning and Logical Mathematical Intelligence have individual effects on the Attitude towards Physics.

To assess the differences between groups in Logical Mathematical Intelligence, Scheffé's post hoc test for comparisons was employed. The corresponding results are presented in the table 24 below.

Table 24

Scheffé's Post-hoc Test for Comparisons for Logical Mathematical Intelligence

Group		Mean Difference	Std. Error	Sig.
Low Logical Mathematical Intelligence (M =273.25)	Average Logical Mathematical Intelligence (*M*= 278.45)	5.23	1.19	.001
Low Logical Mathematical Intelligence	High Logical Mathematical Intelligence (*M*= 285.78)	12.53	1.46	.001
Average Logical Mathematical Intelligence	High Logical Mathematical Intelligence	7.29	1.13	.001

The mean difference between the low Logical Mathematical Intelligence group (M = 273.25) and the average Logical Mathematical Intelligence group (M = 278.45) is 5.23. The standard error is 1.19, and the p-value is 0.001 (indicating statistical significance). Therefore, the mean Attitude towards Physics score of the average group is significantly higher than that of the low group. The mean difference between the low Logical Mathematical Intelligence (M = 273.25) and the high Logical Mathematical Intelligence (M = 285.78) is 12.53. The standard error is 1.46, and the p-value is 0.001 (indicating statistical significance). This suggests that the mean Attitude towards Physics score of the high group is significantly higher than that of the low group. The mean difference between the average Logical

Mathematical Intelligence (M = 278.45) and the high Logical Mathematical Intelligence (M = 285.78) is 7.29. The standard error is 1.13, and the p-value is 0.001 (indicating statistical significance). Therefore, the mean Attitude towards Physics score of the high group is significantly higher than that of the average group.

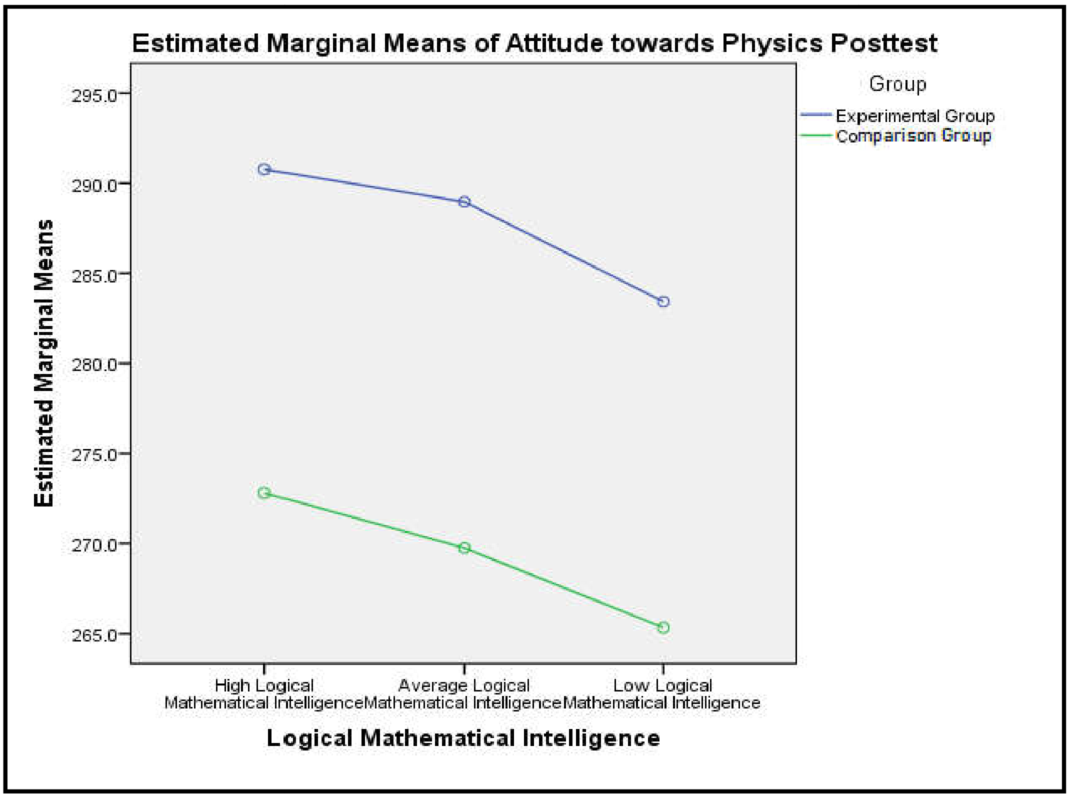
Conclusion

The two-way ANOVA analysis shows that there is no significant interaction effect between instructional strategy and Logical Mathematical Intelligence on attitude towards Physics

A graphical representation of the interaction effect of Concept Mapping Strategy in Problem-Based Learning and Logical Mathematical Intelligence on Attitude towards Physics is presented in the figure 20 below.

Figure 20

Graphical Representation of the Interaction Effect of Instructional Strategy and Logical Mathematical Intelligence on Attitude towards Physics



Conclusion

The analysis and interpretation of the research revealed that there is a significant effect Concept Mapping Strategy in Problem-Based Learning on enhancing achievement in Physics and Attitude towards Physics.

Chapter 5

SUMMARY & CONCLUSION

- *Study in Retrospect*
- *Major Findings of the Study*
- *Tenability of Hypotheses*
- *Conclusion*

'Chapter 5- Summary, Conclusion, & Suggestions' presents the entire study in a summarised form, focusing on key findings of the study, tenability of research hypotheses, obtained conclusions, educational implications and limitations of the study, along with relevant suggestions for further research.

Study in Retrospect

This section is a revisit of the title of this study, variables, objectives, hypotheses, tools and statistical techniques used in this study.

Title of Study

The present study is entitled "EFFECT OF CONCEPT MAPPING STRATEGY IN PROBLEM-BASED LEARNING ON ACHIEVEMENT AND ATTITUDE TOWARDS PHYSICS AMONG HIGHER SECONDARY SCHOOL STUDENTS."

Variables

Independent Variables

The independent variables can be defined as the conditions or characteristics that the researcher manipulates or controls in his or her attempt to find out their relationship to the observed phenomena. Here, in this study, instructional strategy (Concept mapping strategy in Problem-Based Learning) was treated as an independent variable.

Dependent Variables

The dependent variables can be defined as the conditions or characteristics that may appear, disappear or varies as the researcher introduces, maintains or changes the independent variables. Also, the dependent variable is the outcome upon which the researcher compare the independent variable in an experiment. Here, in this study, achievement and attitude towards Physics are the dependent variables

Controlled Variables

In this study, the controlled variables are Non-Verbal Intelligence and Logical Mathematical Intelligence.

Objectives of the Study

The main objectives of the study are,

1 To find out the effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning/Problem-Based Learning without Concept Mapping Strategy) on achievement in Physics of Higher Secondary School students.

2 To find out the effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning /Problem-Based Learning without Concept Mapping Strategy) on attitude towards Physics among Higher Secondary School students.

3 To study the main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and Logical Mathematical Intelligence on Achievement in Physics for the total sample.

4 To study the main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning /Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on Attitude towards Physics for the total sample.

Hypotheses

The hypotheses formulated for the study are:

1. There will not be any significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) with nonverbal intelligence and logical mathematical intelligence as covariates on achievement in Physics among higher secondary school students.

2. There will not be any significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) with nonverbal intelligence and logical mathematical intelligence as covariates on attitude towards Physics among higher secondary school students.

3. There will not be any significant main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on achievement in Physics for the total sample.

4. There will not be any significant main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on attitude towards Physics for the total sample.

Methodology in Brief

An experimental method is used for the present study. The design selected was the quasi-experimental pretest-posttest, comparison group design (Campbell & Stanley, 1963). The study is to be conducted on a final sample of 100 students of standard XI, and each division consists of 50 students among which one of the divisions is considered to be the experimental group and the other division as comparison group. A comparison has to be done between experimental and comparison groups, consisting of standard XI students, based on their previous physics achievement scores, non-verbal intelligence test scores, logical mathematical intelligence test and pretest scores.

Table 25

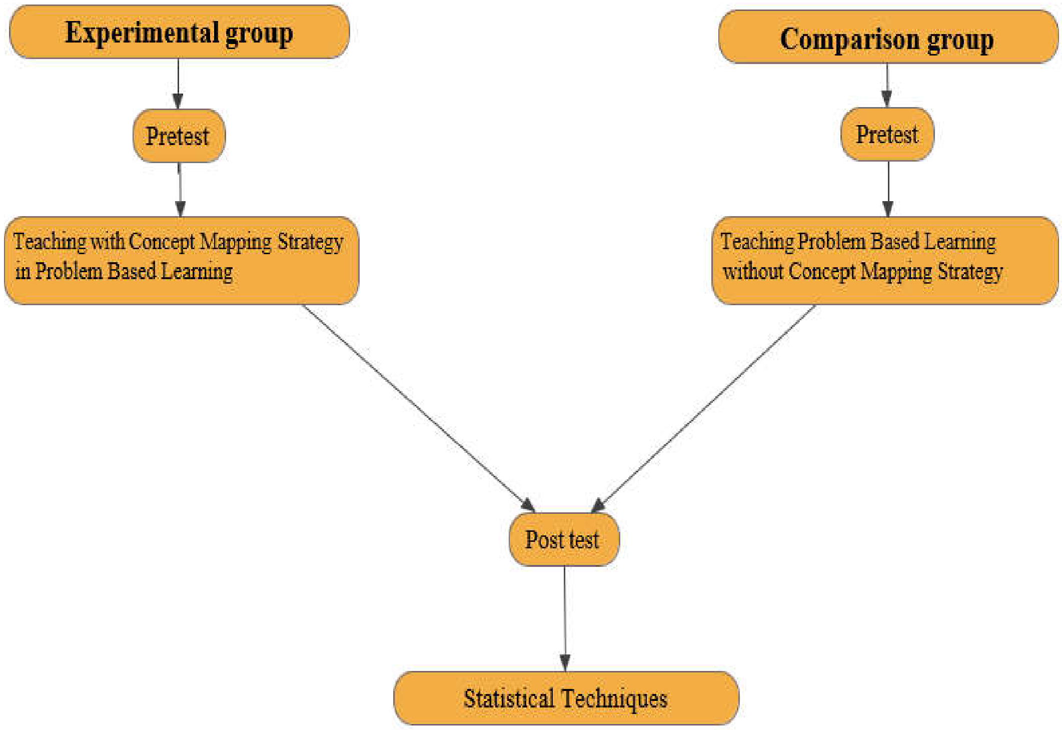
Design of the Study

Stage	Experimental Group	Comparison Group
Pre-test	• Standard Progressive Matrices (non-verbal intelligence) • Logical- Mathematical Intelligence Test • Achievement Test in Physics • Physics Attitude Scale	• Standard Progressive Matrices (non-verbal intelligence) • Logical- Mathematical Intelligence Test • Achievement Test in Physics • Physics Attitude Scale
Treatment	• Teaching with Concept Mapping Strategy in Problem-Based Learning	• Teaching without Concept Mapping Strategy in Problem-Based Learning
Post-test	• Achievement Test in Physics • Physics Attitude Scale	• Achievement Test in Physics • Physics Attitude Scale

A visual representation of the design of the study is given below:

Figure 21

Design of the Study



Statistical Tools used

The statistical tools used for finding out or measuring various aspects led to the successful realisation of the objectives of the study are the following:

Standard Progressive Matrices - Raven's Standard Progressive Matrices (SPM), which was published in 1938, is an examination of a person's capability at the time of the test to interpret meaningless figures presented for observation, see how they are related to each other, and reach a conclusion. By doing so, learners develop a systematic way of reasoning. This scale consists of 60 problems which are divided into five sets of twelve problems in each. The first problem self-evident as near as possible. The problems, which then follow, become progressively difficult to interpret, interrelate and conclude. The order of items, followed in the scale, provides a standard training for the learners in the way of working. The five sets, with twelve problems each, provide five opportunities for the learners to grasp the method and offer five progressive assessments of a person's capability for intellectual activity. To ensure constant interest and reduce fatigue, the figure in each problem is presented boldly, actually drawn in a pleasing way to look at.

Logical Mathematical Intelligence Test. The Logical Mathematical Intelligence test was adopted from the study Effect of Schema-Based Instruction on Solving Story Problems in Physics Among Higher Secondary School Students (Vijesh, 2019) developed by Vijesh and Manoj Praveen based on the Logical Mathematical Component of the theory of multiple intelligences proposed by Gardner (1983). The items of this test were developed with an intention to measure thirteen components of logical Mathematical Intelligence, viz., 1. Classification 2. Logical pattern recognition 3. Logical diagram analysis 4. Coding and Decoding 5. Ordering 6. Direction sense 7. Information analysis 8. Drawing logical assumptions 9. Understanding the relationship between cause and effect 10. Analogy 11. Syllogism 12. Symbol manipulation 13. Computing ability.

Achievement test in Physics. An achievement test is constructed by the investigator to find out whether the concept mapping strategy in problem-based learning and problem-based learning without the concept mapping approach had any impact on the achievement and attitude of students in physics. For the above-mentioned purpose, the investigator pooled questions based on the selected concepts. A total of ten concepts were selected from the higher secondary physics. The test included all types of questions, like objectives, short-answer type, as well as essay-type items. The achievement test was constructed by considering the revised

Bloom's taxonomy in mind. Items were testing the attainment of the six levels of objectives, namely knowledge, understanding, applying, analysing, evaluating and creating (Anderson, 2001).

Physics Attitude Scale. A Physics Attitude Scale (PAS) was adopted from the study 'Development of Physics Attitude Scale (PAS): An Instrument to Measure Students' Attitudes Toward Physics' (Kaur & Zhao, 2017) to measure students' attitude towards physics among Higher Secondary School students.

In the above-mentioned Physics Attitude Scale (PAS), there are sixty items under the following five factors: 1. Enthusiasm towards physics 2. physics learning, 3. physics as a process, 4. physics teacher, 5. Physics as a future vocation. Out of these 60 items, 27 are positive and 33 are negative statements. Each item is given with an opportunity for learners to give live responses ranging from strongly agree (S.A), agree (A), undecided (U.D), disagree (D), and strongly disagree (S.D). Students are required to read and analyse each item in the test in a careful manner and mark the response that they themselves feel as most appropriate. It is necessary to attend all the items, and this test has no specific time limit as well as no fixed right or wrong answers. The scoring system is as follows: Positive Statements (+ve): Strongly Agree (S.A) - 5, Agree (A) - 4, Undecided (U.D) - 3, Disagree (D) - 2, Strongly Disagree (S.D) - 1.; Negative Statements (-ve): Strongly Agree (S.A) - 1, Agree (A) - 2, Undecided (U.D) - 3, Disagree (D) - 4, Strongly Disagree (S.D) - 5

Statistical Techniques Used

To analyse the acquired data in the study, the following statistical techniques were used:

t-test. A t-test is a statistical test employed for comparing the means of two groups under consideration and determine if there is a statistically significant difference between them.

Analysis of Covariance (ANCOVA). ANCOVA is a statistical technique to compare sets of data containing one or more means by controlling the effects of one or more covariates (In this study, non-verbal intelligence and logical mathematical intelligence)**.** This technique is useful for adjustment of dependent variable (achievement in physics or attitude towards physics in this case) for linear effects of covariates to obtain a clear understanding of the effectiveness of the instructional strategy.

Two-Way Analysis of Variance (Two-Way ANOVA). Two-way Analysis of Variance is employed to compare the effect of two independent variables (instructional strategy and logical-mathematical intelligence in this case) on a dependent variable (achievement in Physics and attitude towards physics in this case). Also, this technique tests for interaction effects that indicate whether the effect of one independent variable on the dependent variable changes across levels of the other independent variables.

Scheffé's Post Hoc Test. The Scheffe test is a post-hoc test employed for analysis of variance (ANOVA) to find out which specific group means vary significantly from one another after an overall significant difference has been found.

These techniques will help in analysing whether the instructional strategies have a significant impact on achievement in Physics and attitude towards Physics, taking into account their levels of nonverbal and logical-mathematical intelligence.

Major Findings of the Study

Major findings of this study are given below.

- There was a significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) on Achievement in Physics among Higher Secondary School students with nonverbal and Logical Mathematical Intelligence as covariates.
- There was a significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) on Attitude towards Physics among Higher Secondary School students with covariates viz. nonverbal intelligence and Logical Mathematical Intelligence.
- There was a significant main effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and Logical Mathematical Intelligence on achievement in Physics among Higher Secondary School students
- There was no significant interaction effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and Logical Mathematical Intelligence on achievement in Physics among Higher Secondary School students
- There was a significant main effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based

Learning without Concept Mapping Strategy) and logical mathematical intelligence on attitude towards Physics among Higher Secondary School students

- There was no significant interaction effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem-Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on attitude towards Physics among Higher Secondary School students

Tenability of Hypotheses

- **Hypothesis 1 states that "There will not be any significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem Based Learning without Concept Mapping Strategy) with nonverbal intelligence and logical mathematical intelligence as covariates on achievement in Physics among higher secondary school students".**

The ANCOVA with instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem Based Learning without Concept Mapping) as the independent variable and Achievement (total gain score of Achievement in Physics) as the dependent variable, treating the controlled variables namely, Non Verbal intelligence and Logical Mathematical Intelligence, as covariates determined that there was a significant effect of instructional strategy on Achievement in Physics among Higher Secondary School students with Non-verbal Intelligence and Logical Mathematical Intelligence as covariates. **The hypothesis is rejected.**

- **Hypothesis 2 states that "*There will not be any significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning/ Problem Based Learning without Concept Mapping Strategy) with nonverbal intelligence and logical mathematical intelligence as covariates on attitude towards Physics among higher secondary school students.***

  The ANCOVA with instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem Based Learning without Concept Mapping) as the independent variable and Attitude towards Physics (total gain score of Attitude towards Physics) as the dependent variable, treating the controlled variables namely, Non-Verbal intelligence and Logical Mathematical Intelligence as covariates found out that there was a significant effect of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem Based Learning without Concept Mapping)on Attitude towards Physics among Higher Secondary School students with Non-verbal Intelligence and Logical Mathematical Intelligence as covariates. **The hypothesis is rejected.**

- **Hypothesis 3 states that "*There will not be any significant main effects and interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on achievement in Physics for the total sample".***

  The two-way ANOVA performed for the total sample with factors instructional strategy (Concept Mapping Strategy in Problem-Based Learning /Problem Based Learning without Concept Mapping) and

Logical Mathematical Intelligence upon the Achievement in Physics concludes that:

- Instructional strategy and Logical Mathematical intelligence have no significant interaction effect on Achievement in Physics at the 0.05 level.
- Instructional strategy and Logical Mathematical intelligence have a significant main effect on Achievement in Physics at the 0.01 level.

Hence, the hypothesis is partially accepted.

- **Hypothesis 4 states that "*There will not be any significant main effects or interaction effects of instructional strategy (Concept Mapping Strategy in Problem-Based Learning / Problem Based Learning without Concept Mapping Strategy) and logical mathematical intelligence on attitude towards Physics for the total sample*".**

The two-way ANOVA employed for the total sample with factors viz., instructional strategy (Concept Mapping Strategy in Problem-Based Learning/ Problem Based Learning without Concept Mapping) and Logical Mathematical Intelligence upon the Attitude towards Physics concludes that:

- Instructional strategy and Logical Mathematical intelligence have no significant interaction effect on Attitude towards Physics at the 0.05 level.
- Instructional strategy and Logical Mathematical intelligence have a significant main effect on Attitude towards Physics at the 0.01 level.

Hence, the hypothesis is partially accepted.

Conclusion

Investigating the effect of the Concept Mapping strategy in Problem-Based Learning will give us valuable insights into how pedagogy should evolve for improved science education. This study, entitled “EFFECT OF CONCEPT MAPPING STRATEGY IN PROBLEM BASED LEARNING ON ACHIEVEMENT AND ATTITUDE TOWARDS PHYSICS AMONG HIGHER SECONDARY SCHOOL STUDENTS,” found out a positive effect of instructional strategy on Achievement and Attitude towards Physics among Higher Secondary School students. After giving the above-mentioned instructional strategy as an experimental intervention, students of the experimental group have shown appreciable improvement in their Achievement and Attitude towards Physics compared to the comparison group, which was taught without the Concept Mapping Strategy in Problem-Based Learning

This study mainly studied the effect of instructional strategy with nonverbal intelligence and logical mathematical intelligence as covariates on Achievement and Attitude towards Physics among higher secondary school students. The findings revealed that there was a significant effect of Concept Mapping Strategy in Problem-Based Learning in Achievement and Attitude Towards Physics Among Higher Secondary School students with Logical Mathematical Intelligence and Nonverbal Intelligence as covariates.

The study also investigated the main effects or interaction effects of instructional strategy and Logical Mathematical Intelligence on Achievement and Attitude towards Physics among Higher Secondary School students. The results of this study showed that there was a significant main effect of instructional strategy and logical mathematical intelligence on Achievement and Attitude towards Physics among Higher Secondary School students, while there was no significant interaction effect of instructional strategy and Logical Mathematical Intelligence on Achievement and Attitude towards Physics among Higher Secondary School students.

Chapter 6

RECOMMENDATIONS

- *Educational implications*
- *Recommendations*

Numerous researches have to be conducted for meeting the diverse educational needs of the society. The conduct of widespread research provides data-driven recommendations for the positive evolution of the educational field. In the world of rapid growth of science and technology, it's indispensable to replace old concept or methods of science teaching with innovative instructional strategies that justifies the need to know the present position and progress of science to obtain an adequate knowledge of the world in which we are living. This study investigates the effect of Concept Mapping strategy in Problem-Based Learning approach providing us with valuable insights into how pedagogy should evolve and innovative instructional strategies should be developed for effective science education pathways in the current world of rapid changes in the field of science and technology. This study revealed a positive effect of instructional strategy on Achievement and Attitude towards Physics among Higher Secondary School students.

For any research, the educational implications help us to translate research findings to meaningful and practical actions to revolutionise the field of education as well as ensure that the research work contributes to the advancement of teaching learning strategies. These implications act as guidance for educators on how to improve the teaching learning process to a more effective and scientific one. At the same time, recommendations for further research are equally important as they identify the research gaps, limitations of current research and answer the new questions emerged from the findings of the study. Educational implications and recommendations keep the cycle of inquiry active and ensure the field of education remains dynamic and responsive to changing needs. This chapter presents the educational implications of this research study along with recommendations for further research in the area under consideration.

Educational Implications

> *Instruction should be geared not just toward imparting a knowledge base, but toward developing reflective, analytical, creative, and practical thinking with a knowledge base. Students learn better when they think to learn. They also learn better when teaching takes into account their diverse styles of learning and thinking.*
>
> (Sternberg, 1998).

The investigator felt that the present instructional strategies are not adequate to help the students in understanding concepts in Physics in Higher Secondary classes, which highlights the need for a more adaptable and flexible instructional strategy to offer effective educational pathways. This study demonstrated how 'integrating Concept Mapping strategy in Problem-Based Learning approach' as a novel instructional strategy was effective in enhancing Achievement and Attitude towards Physics among Higher Secondary School students. Hence, this research study advocates the implementation of the above-mentioned instructional strategy in the field of education.

Findings of this study has significant implications in the field of education, particularly in the teaching learning process of science subjects such as Physics at Higher Secondary level. They are:

1. Promoting Innovative Teaching Strategies

The study shows the positive effect of integrating Concept Mapping strategy with Problem-Based Learning (PBL) approach as an effective alternative to the traditional instructional methods. Using these two strategies together results in a student-centred approach which shifts the focus from passive reception of information to active learning.

It is recommended that educators in the field of science should take initiatives to implement innovative teaching strategies like "Integration of Concept Mapping Strategy to Problem Based Learning Approach" as early as possible to enhance learning outcomes of the students and thereby enhance the effectiveness of prevalent educational setup.

2. Incorporating into the Physics Curriculum and the Teacher's Handbook

The instructional strategy (Concept Mapping Strategy in Problem-Based Learning) demonstrated in this study can be incorporated into the Higher Secondary Physics curriculum and the teacher's handbook. Also, there is a beneficial scope for resource development to support the implementation of this instructional strategy.

Hence, this study recommends redesigning of learning resources and teachers handbook of Physics at Higher Secondary Level.

3. Redefining the Role of Teacher

Modern pedagogical principles of constructivist learning propose the idea that learners are active participants in the process of knowledge construction. Adoption of this innovative strategy shifts the role of teachers from mere transmitters of information to the facilitators of learning where the learners are active participants in the learning process. As a result, teachers are entrusted with the responsibility of guiding and supporting the students as they explore concepts, deduce inferences, create connections, and derive conclusions in an independent manner.

It is thus recommended that teachers should be given a suitable educational setting, with professional development training, in the prevalent educational landscape to adopt this innovative strategy which leads to a constructivist learning experience for students by designing learning environments that encourage active student participation, inquiry-based exploration, and collaborative problem-solving. Professional development programs focus on equipping teachers with the skills in implementing this innovative teaching strategy enabling them to act as facilitators rather than sole providers of knowledge.

4. Scope for Pre-service/In-service Professional Development Training/ Workshops

The present study suggests the use of an Instructional strategy (Concept Mapping Strategy in Problem-Based Learning) for teaching learning process of Physics at the Higher Secondary School level. Thus, Higher secondary school teachers may be given pre-service/in-service professional development training/workshops for the proper implementation of this instructional strategy in the teaching and learning process.

For this purpose, it is recommended to construct a module at the state/national level for the broad training of in-service Higher Secondary school teachers. Also, there is a scope for module to train learners for effective participation in this instructional strategy may also be attempted.

5. As an Assessment Tool

Another noteworthy implication of this innovative instructional strategy is the scope of this strategy to be used in formative as well as summative assessment practices. Teachers can use this innovative strategy to assess not only the final products of learning but also the process of learning itself, such as the refinement in comprehension of students' concepts over time, through the improvement in the construction of concept maps. This results in a more comprehensive and holistic evaluation of students' understanding and cognitive development.

It is thus recommended that assessment practices incorporate this instructional strategy as a basis for both formative and summative evaluation in the field of education. This involves redesigning of assessment policies and providing training for teachers to use this instructional strategy not only as learning aids but also as diagnostic instruments to assess conceptual understanding of students. This results in emergence of an authentic assessment practice that values conceptual understanding, self-reflection, and critical thinking alongside final outcomes.

6. Requirement of a New Assessment Technique that Assess the Attributes of this New Instructional Strategy

Implementation of the instructional strategy (Concept Mapping Strategy in Problem-Based Learning) demonstrated in this study highlights the requirement for employing a new assessment technique which is capable of assessing the attributes of this new instructional strategy. This newly formulated assessment technique should give due importance to assessing the ability to construct concept maps and to identify important conceptual elements in the problem situation by means of concept maps.

Hence, it is recommended to introduce this innovative strategy by redesigning curriculum at different levels of education to give scope for learning by integrating Concept Mapping Strategy in Problem Based Learning approach empowering the students to take the ownership of their learning process.

7. Enhancement of Conceptual Understanding and Higher-Order Thinking

Assuring conceptual understanding can replace rote learning thereby enabling the students to bridge the gap between classroom learning and real life applications in a more effective manner. This innovative strategy has found to be advantageous in facilitating deeper conceptual understanding. Use of concept maps in learning process enables students to visually organise and correlate concepts, which results in active meaningful learning and thereby deeper conceptual understanding of the concepts.

Educational policies, like NEP 2020, suggests the promotion of critical thinking and problem-solving skills through analysis of data and solving real-world problem scenarios. It is thus recommended to adopt this innovative instructional strategy especially in the field of science education as when concept mapping activity is paired with real-world problem-solving scenarios, the approach will effectively enhance critical thinking, analytical reasoning, and expertise in application of knowledge, all of which are essential components of higher-order cognitive skills in the field of science education.

8. Nurturing Independent and Self-Regulated Learning among Students

By means of this innovative pedagogy, they learn how to organise information, identify important crosslinks and relationships, and synthesise knowledge, which promotes self-directed learning skills in a direct manner. Thus, when students are engaged with concept mapping and problem-solving scenarios, they become independent in their learning processes, taking the responsibility of learning by themselves.

9. Suitability for Diverse Learners Classrooms

The findings of this study also suggest that the Concept Mapping–PBL strategy is effective across learners with diverse needs in terms of levels of student intelligence and academic ability or skills. It enables learners to adapt their own pace of learning, making it an inclusive approach that clearly supports the method of differentiated instruction.

It is thus recommended that educators adopt this innovative and inclusive approach which supports differentiated instruction enabling the teachers to tailor lessons to meet diverse learning needs of all students in a classroom.

10. Transformation of Science Classrooms

Integration of Concept Mapping strategy within a Problem-Based Learning framework has the capability to transform traditional teacher-centred science classrooms into more interactive, reflective and continuously assessed student-centred learning environments. By transforming the learning process to a more meaningful and engaging one, it can notably improve both the achievement and attitude of students towards Physics and science learning in general.

It is thus recommended that science education should be restructured to incorporate Concept Mapping strategy within a Problem-Based Learning (PBL) framework as this pedagogical transformation promotes to shift classrooms from traditional, teacher-centred instruction toward more interactive, self reflective, and student-centred learning environments. Curriculum designing and classroom practices has to be restructured in such a way that it prioritize this approach by integrating it into science syllabi, providing teachers with adequate professional development, and encouraging classroom practices that focus on transforming teachers from mere knowledge transmitters to facilitators.

11. Improved Theory Exam Marks

In the current educational setup, the outcome of a learning process in higher secondary education is mainly measured through the theory exams conducted at the end of the course duration. Through this study, it was found that integrating the Concept Mapping Strategy in the Problem-Based Learning Approach has a positive impact on student achievement, leading to improved theory exam marks. Also, this study demonstrated that integrating the Concept Mapping Strategy in the Problem-Based Learning Approach has a positive impact on attitude towards physics among Higher Secondary School students. A student's attitude has a positive effect on his/her academic achievement (Malala et al., 2021).

Thus it is recommended that this new instructional strategy which improves attitude, which in turn enhances academic achievement, leading to improved theory exams should be adopted in the instructional practices at the Higher Secondary level Physics.

12. Implementation in Various Disciplines at Different Levels of Education

The instructional strategy (Concept Mapping Strategy in Problem-Based Learning) demonstrated in this study can be implemented in various disciplines at different levels of education for a positive effect on achievement and attitude towards respective subject areas. In this way, the pedagogical implications of this instructional strategy can be realised to their full potential.

Recommendations for Further Study

The limitations and educational implications of present study prompt recommendations for further research in the area of research under consideration as follows:

- The present study was limited to the discipline of Physics. Future researchers can examine the effect of Concept Mapping Strategy in Problem-Based Learning in other disciplines, for example, science disciplines like Chemistry and Biology, and Arts and Humanities.
- The present study was limited to the higher secondary level of education. Further research can be conducted by carrying out the present study at various other levels and domains of education, like university education, medical education, etc.
- The present study was conducted within Kerala, India. Future researchers can explore the effect of Concept Mapping Strategy in Problem-Based Learning in other educational contexts outside Kerala, India.
- The present study was conducted in a Higher Secondary school following the Kerala SCERT syllabus. Future researchers can conduct the same study in schools following other syllabi, such as CBSE schools.
- In the present study, the effect of Concept Mapping Strategy in Problem-Based Learning on Achievement and Attitude towards Physics among Higher Secondary School students was investigated. Future research can be conducted by considering dependent variables other than achievement and attitude.

- Further study can be conducted by integrating other teaching strategies in place of the concept mapping strategy with the Problem-Based Learning approach.
- The present study was conducted in a formal classroom setup. Future research can be conducted in other educational scenarios like virtual learning environments, distance mode of learning.
- The present study was conducted by relying on the traditional pen and paper method. Future research can be carried out by employing computer-based instruction.

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APPENDICES

- ***Logical Mathematical Intelligence Test***
- ***Lesson Transcript based on Concept Mapping Strategy in PBL***
- ***Lesson Transcript based on PBL without Concept Mapping Strategy***
- ***Achievement Test in Physics***
- ***Physics Attitude Scale***

Appendix A1

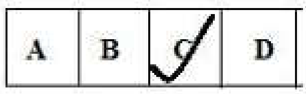
DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

LOGICAL MATHEMATICAL INTELLIGENCE TEST

Dr.VIJESH K **Dr. MANOJ PRAVEEN G**

Instructions

1. This booklet contains 36 multiple choice questions, each worth 1 mark. (No negative mark)
2. Do not write anything on this booklet.
3. Answer all questions. Each question is followed by four choices (A,B,C,D), one of which is correct. You will record your responses on a separate answer sheet.
4. When marking answers on the answer sheet, for each question, Put [√] mark only on the box corresponding to the right answer. E.g. If the right answer is C ,



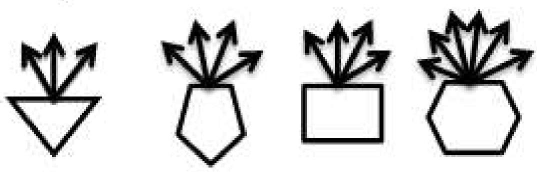
5. Make sure that your answer is clearly marked.
6. After the test please return this booklet along with answer sheet to the invigilator.

Directions: ***Three of the following four are alike in a certain way and so form a group. Which is the one that does not belong to that group?***

1. (A) 81 **(B)** 41 **(C)** 36 **(D)** 25

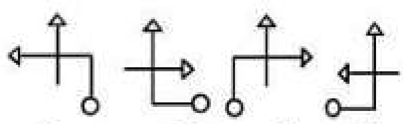
Choose the figure which is different from the rest

2.



(A) **(B)** **(C)** **(D)**

3. Which of the figure, you think best fits the series below?



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

4. Identify the next number in the series,

9, 8, 8, 8, 7, 8, 6, ……….

(A) 5 (B) 6 (C) 8 (D) 4

5. Arrange the given words in alphabetical order and pick the one that comes first.

(A) NATURE (B) NATIVE (C) NARRATE (D) NASCENT

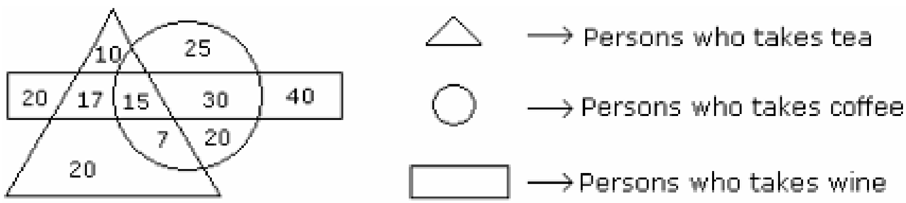
6. If the first and the third letters in the word NECESSARY were interchanged, also the fourth and the sixth letters and the seventh and the ninth letters, which of the following would be the 7th letter from the left?

(A) Y (B) R (C) E (D) A

7. In certain code **'FORM'** is written as **'ERQP'** How will **'CLEAN'** be written in that code?

(A) BOFDO (B)GKHBQ (C) BODDM (D)GMKBQ

Analyze the diagram given below and answer each of the following questions:



8. How many persons who take tea and wine but not coffee?

(A) 20 (B) 17 (C) 25 (D) 15

Read the following information carefully and answer the question given below

9. Veena went to North. Then she turned right and proceed. Then she turned left and walked 5 km. Finally she turned left again. In which direction was she moving then?

(A) South (B) North (C) West (D) East

10. Tom walked 8 km towards south and turned right. After walking 5 km he turned to the left and walked 8 km. Then in which direction was he from the starting point.

(A)North-East (B) South- West (C) North-West (D) South –East

11. Rahul ranked ninth from the top and thirty eight from the bottom in a class. How many students are there in the class?

(A) 47 (B) 52 (C) 46 (D) 50

12. How many 6's are there in the following number series which are immediately preceded by 4 and followed by 7?

3, 1 ,2, 9, 6, 4, 7, 6, 4, 6 ,7 ,2 , 9, 7, 6, 4 , 4, 6, 7

(A)One (B) Two (C) Three (D) Four

Directions: ***In each question below, is given a statement followed by two assumptions numbered I and II. You are required to assess the given statement and decide which of the given assumptions is implicit in the statement.***

13. Statement: It is desirable to put the child in the school at the age of 5 or so

Assumptions:

I. At that age the child reaches appropriate level of development and ready to learn.

II. The school do not admit children after six years of age.

(A)Only assumption **I** is implicit (B) Only assumption **II** is implicit

(C) Both I and **II** are implicit (D) Neither I nor **II** are implicit

Directions: ***In each of the following questions, two statements numbered I and II are given. There may be cause and effect relationship between the two statements. These two statements may be the effect of the same cause or independent causes. These statements may be independent causes without having any relationship. Read both the statements in each question and mark your answer.***

14. Statements:

I. The government has recently fixed the fees for professional courses offered by the unaided institutions which are much lower than the fees charged last year.

II. The parents of the aspiring students launched a severe agitation last year protesting against the high fees charged by the unaided institutions.

(A) Statement I is the cause and statement II is its effect

(B)Statement II is the cause and statement I is its effect

(C) Both the statements I and II are independent causes

(D) Both the statements I and II are effects of independent causes

15. Statements:

I. The school authority has asked the X Std. students to attend special classes to be conducted on Sundays.

II. The parents of the X Std. students have withdrawn their wards from attending private tuitions conducted on Sundays.

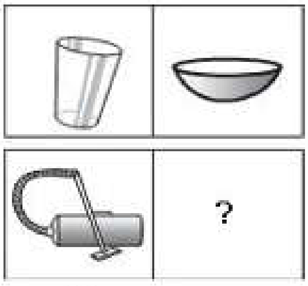
(A) Statement I is the cause and statement II is its effect

(B) Statement II is the cause and statement I is its effect

(C) Both the statements I and II are independent causes

(D) Both the statements I and II are effects of independent causes

16. Directions: ***Choose the picture that would go in the empty box so that the two bottom pictures are related in the same way as the top two are related***



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

17. If **K= 2P + 2W** then pick out the correct one

(A) W= $\frac{K}{2P}$ **(B) W=** $\frac{K-2P}{2}$ **(C) W=** $\frac{2P-K}{2}$ **(D) W=** $\frac{K+2P}{2}$

18. If- means x, x means +, + means ÷ and ÷ means – what will be the value of

40x12+3-6÷60 =….?

(A) 44 (B) 7.95 (C) 4 (D) 8

Directions: ***In each question below are given two statements followed by two conclusions numbered I and II. You have to take the given two statements to be true even if they seem to be at variance from commonly known facts. Read the conclusion and then decide which of the given conclusions logically follows from the two given statements, disregarding commonly known facts.***

19. Statements: Some clips are green. All greens are red

Conclusions: I. All clips are red **II.** Some clips are red

(A) Only conclusion I follow (B) Only conclusion II follows

(C) Neither I nor II follows (D) Both I and II follow

20. Statements: All planets are moons. All moons are stars.

Conclusions: I. All moons are planet **II.** All planets are stars

(A) Only conclusion I follow (B) Only conclusion II follows

(C) Neither I nor II follows (D) Both I and II follow

21. January 1, 2007 was Monday. What Day of the week on January 1, 2008?

(A) Monday (B) Tuesday (C) Wednesday (D) Sunday

22. If 25th August is Thursday, how many Mondays are there in August

(A) 3 (B) 4 (C)5 (D) 6

23. If the day after tomorrow is Sunday, what was the day before yesterday?

(A) Friday (B) Thursday (C) Wednesday (D) Saturday

24. Ajayan left home for the bus stop 15 minute earlier than usual. It takes 10 minute to reach the stop. He reached the stop at 8.40 AM. What time does he usually leave home for the bus stop?

(A) 8:30 AM (B) 8:45 AM (C) 8:55 AM (D) 8:25 AM

25. A watch reads 4:30. If the minute hand points east, then in which direction will hour hand point?

(A) North (B) North-East (C) South-East (D) North-West

26. The ages of Pinky, Rinky, Tinky and Minky are 20 yr., 15yr, 5yr, and 8yr respectively. The average age of the four girls is ....

(A) 18 yr. (B) 12 yr. (C) 15 yr. (D) 13 yr.

27. The average age of 36 students in a group is 14 years .When teacher's age is included to it, the average increases by one. What is the teacher's age in years?

(A) 31 (B) 36 (C) 51 (D) 28

28. A does a work in 10 days and B does the same work in 15 days .In how many days they together will do the same work ?

(A) 6 days (B) 25 Days (C) 12 days (D) 5 days

29. A is twice as fast as B and B is thrice as fast as C. The Journey covered by C in 42 minutes will be covered by A in .....

(A) 7 min. (B)14 min. (C)28min. (D)63min.

30. In a school there are 256 students; boys and girls are in the ratio 9:7. Then the number of girls is

(A) 56 (B) 112 (C) 84 (D) 67

31. The sum of two numbers 40. Their difference is 4. The ratio of the number is

(A) 10:9 (B) 9:11 (C) 11:9 (D) 9:10

32. 24÷ 6(10-4) - 18+2=.......?

(A) 8 (B) 1.5 (C) 40 (D) 44

33. 4 of $\frac{3}{8} \div \frac{3}{8} + \frac{1}{7}$ = ...?

(A) $7\frac{1}{4}$ (B) $1\frac{4}{7}$ (C) $4\frac{1}{7}$ (D) $\frac{10}{71}$

34. 50 + 50 % of 50 is.........

(A) 60 (B) 70 (C) 75 (D) 100

35. In an examination 65% of the total students passed. If the number of failures is 420, the total number of students is ......

(A) 500 (B)1200 (C) 1000 (D)1625

36. The sum of the ages of father and a sun is 52. The difference of their ages is 28 then the age of the father is .....

(A) 48 (B) 34 (C) 40 (D) 36

Appendix A2

DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

LOGICAL MATHEMATICAL INTELLIGENCE TEST

RESPONSE SHEET

Name of the student: ………………………………. Gender: Male / Female

Class:….Subject: ……….……..Name of the School :……………………..

Category: Government / Aided / Private

- Put [✓] mark only on the box corresponding to the right answer.

  eg: If the right answer is C,

A	B	✓C	D

Q No:					Q No:					Q No:				
1	A	B	C	D	13	A	B	C	D	25	A	B	C	D
2	A	B	C	D	14	A	B	C	D	26	A	B	C	D
3	A	B	C	D	15	A	B	C	D	27	A	B	C	D
4	A	B	C	D	16	A	B	C	D	28	A	B	C	D
5	A	B	C	D	17	A	B	C	D	29	A	B	C	D
6	A	B	C	D	18	A	B	C	D	30	A	B	C	D
7	A	B	C	D	19	A	B	C	D	31	A	B	C	D
8	A	B	C	D	20	A	B	C	D	32	A	B	C	D
9	A	B	C	D	21	A	B	C	D	33	A	B	C	D
10	A	B	C	D	22	A	B	C	D	34	A	B	C	D
11	A	B	C	D	23	A	B	C	D	35	A	B	C	D
12	A	B	C	D	24	A	B	C	D	36	A	B	C	D

TOTAL SCORE	

Appendix A3

DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

LOGICAL MATHEMATICAL INTELLIGENCE TEST

SCORING KEY

Q.NO	ANS
1	B
2	B
3	A
4	C
5	C
6	A
7	C
8	B
9	C
10	B
11	C
12	B
13	A
14	B
15	A
16	A
17	B
18	C

Q.NO	ANS
19	B
20	B
21	B
22	C
23	C
24	B
25	B
26	B
27	C
28	A
29	A
30	B
31	C
32	A
33	C
34	C
35	B
36	C

Appendix B1

DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

LESSON TRANSCRIPT BASED ON CONCEPT MAPPING STRATEGY IN PROBLEM BASED LEARNING

Name of Teacher	: Sunil K	Class: 11
Unit	: Motion in a Straight Line	
Lesson	: Types of Motion Based on Dimensions and Rectilinear Motion	

Learning Objectives:

During/at the end of the class, students will be able to

1. Define motion with examples
2. Observe and identify the patterns of motion in different scenarios (ball, bird, ant).
3. Distinguish between one, two, and three-dimensional motion with relevant examples.
4. Define rectilinear motion and explain its characteristics, providing examples.
5. Construct and modify concept maps to organize, visualize, and understand relationships between the concepts of Rectilinear Motion.

Major Concepts / Learning Points:

1. Motion and types of motion (one dimensional, 2 dimensional, 3 dimensional).
2. Direction as a feature of motion; importance of direction in rectilinear motion (ant's movement).

3. Analysis of problem based on KWHLAQ strategy
4. Use of concept mapping to organize motion-related concepts.

Problem:

Consider the below three cases of motion:

1. A ball thrown in the air
2. A flying bird
3. An ant walking on a tight thread

Analyse the aspects of motion exhibited by each scenario with an aim to understand the significance of recording the direction of an ant as it moves along the string noting down relevant details observed. Compare and contrast the motion of the ball, bird, and ant in terms of their motion pattern, directionality and unique characteristics (if any).

Process Skills:

Observing, analysing, inferring

Pre-requisite Knowledge:

Definition of motion, rate of motion, direction of motion, types of motion (circular, uniform and non-uniform), distance, displacement, speed

Learning Resources:

1. Digital tool for concept map construction (draw.io software)
2. Video resources (three cases of motion mentioned in problem)

Phase of Lesson	Teacher Initiatives	Student Learning Process/ Activity	Teacher Reflection
Introduction	Teacher will start the class with an activity to list out a few examples of motion from daily life.	Student may list out following examples (or other than these): 1. Walking and running 2. Riding a bicycle 3. Water flowing down a dam 4. A lift moving up/down 5. Rotation and revolution of earth 6. An ant moving forward on a thread **7.** A stone dropped from a height	Skill of observation of students is analysed
K What do I think I **know**?	Teacher will define motion as change in position of an object with time. Teacher may ask how can they describe motion.	Students will recall that motion can be explained based on the rate of change of distance (speed), rate of change of displacement (velocity), and rate of change of velocity (acceleration)	Pre-requisite knowledge of students is assessed. (Class 8 chapter 9 -Motion and Class 9 chapter 3- Laws of Motion)
	Prior knowledge on motion is required to be developed using a concept map by students.	A concept map based on their prior knowledge with the motion as key idea is drawn. Concept map example: Refer **“Concept map 1”**	Concept maps are assessed to check for learning gap (if any) Students distinguish speed and velocity as follows: speed describes how fast an object moves while velocity describes both speed and direction of motion.

Phase of Lesson	Teacher Initiatives	Student Learning Process/ Activity	Teacher Reflection
W What do I want to learn?	Teacher asks the difference between speed and velocity	Students distinguish speed and velocity as follows: speed describes how fast an object moves while velocity describes both speed and direction of motion.	Teacher recognises that students have identified the one-dimensional motion as a type of motion through this inquiry
	"What if the direction of motion is not changing? Think from the aspect of speed and velocity"	Students will find that speed and velocity will be same if there is no change in direction of motion.	Teacher recognises that students have identified the one-dimensional motion as a type of motion through this inquiry
	"Pick out the examples (if any) of motion of this type which you have listed out in the beginning of class and also write your own examples (minimum two) in which speed and velocity are same.	Students will list out the following: 1. A lift moving up/down 2. An ant moving forward on a thread 3. A stone dropped from a height 4. A train moving forward on a straight track (new example) 5. Light travelling in a straight line (new example)	Teacher recognises that students have to be introduced to the concept of "Rectilinear Motion" Teacher reflects that students are able to compare and contrast rectilinear motion with the examples they have listed out.
	The teacher will introduce rectilinear motion "Motion of objects along a straight line is known as rectilinear motion"	Students will recognise that all examples of motion they have listed out just now, belong to the type of motion called "Rectilinear Motion"	

Phase of Lesson	Teacher Initiatives	Student Learning Process/ Activity	Teacher Reflection
	The following problem scenario is provided along with a video resource: "Consider the below three cases of motion: 1. A ball thrown in the air 2. A flying bird 3. An ant walking on a tight thread Analyse the aspects of motion exhibited by each scenario with an aim to understand the significance of recording the direction of an ant as it moves along the string noting down relevant details observed. Compare and contrast the motion of the ball, bird, and ant in terms of their motion pattern, directionality and uniques characteristics (if any)."	Student will observe three cases of motion in the given video resources and identify that the example of an ant walking on a tight thread is rectilinear motion. Students are not able to find out further details of rectilinear motion except the directionality. Students fail (partially or completely) to analyse the aspect of motion exhibited by other two scenarios.	Development in concept maps are assessed
	In todays class we will analyse these three situation comprehensive manner. Teacher will give a hint that there	From the problem scenario and teacher's guidance, students identify that there is a new set of types of motion to be learned. They are added to	

Phase of Lesson	Teacher Initiatives	Student Learning Process/ Activity	Teacher Reflection
	are three cases of motion considering situational difference in problem scenario and that there is a scope of introducing a new set of different types of motion. They are: 1. One-dimensional Motion/rectilinear motion or motion along a straight line 2. Two-dimensional motion 3. Three-dimensional motion	the concept map. Development in concept map may happen as follows: Refer **"Concept map 2"**	
H How do I find out?	A peer discussion is encouraged by the teacher to analyse the three types of motion in the problem scenario. Teacher will facilitate the discussion reaching a conclusion that 1. Ball thrown in air is an example of 2 dimensional motion **Justification:** When a ball is	Expected results of discussion are as follows: 1.Ball thrown in air **Motion pattern:** The ball moves upward against gravity until its speed becomes zero at the highest point, then comes back down due to gravity. It follows a curved path (parabolic trajectory). It has varying speed;	

Phase of Lesson	Teacher Initiatives	Student Learning Process/ Activity	Teacher Reflection
	thrown into the air at an angle, it follows a curved trajectory (parabolic path). This means it has both vertical motion (up and down) and horizontal motion (forward) at the same time. So, its position changes in a plane (x-axis and y-axis). 2. A flying bird is an example for 3-dimensional motion **Justification**: A bird flying freely in the air can move in all directions: forward/backward, left/right, up/down. It is not restricted to a plane — it uses all three spatial dimensions (x, y, z). The path can change height, direction sideways, and depth simultaneously.	decreasing while going up, zero at the top, and increasing while coming down. **Directionality:** upward then downward along the same path. **Unique behaviour:** Direction changes at the peak. 2. A flying bird **Motion pattern:** The bird's flight is irregular and self-controlled. It can change speed, altitude, and direction at will. The path can be curved, zig-zag, or linear depending on its purpose. **Directionality:** Continuously changing; not restricted to one axis or plane. **Unique behaviour:** Can hover, ascend, descend, or glide. Uses wings to control lift and direction.	
	3. An ant walking on a tight thread is an example for one dimensional motion/rectilinear	3. Ant walking on a tight thread **Motion pattern:** The ant moves	Development in concept maps are assessed

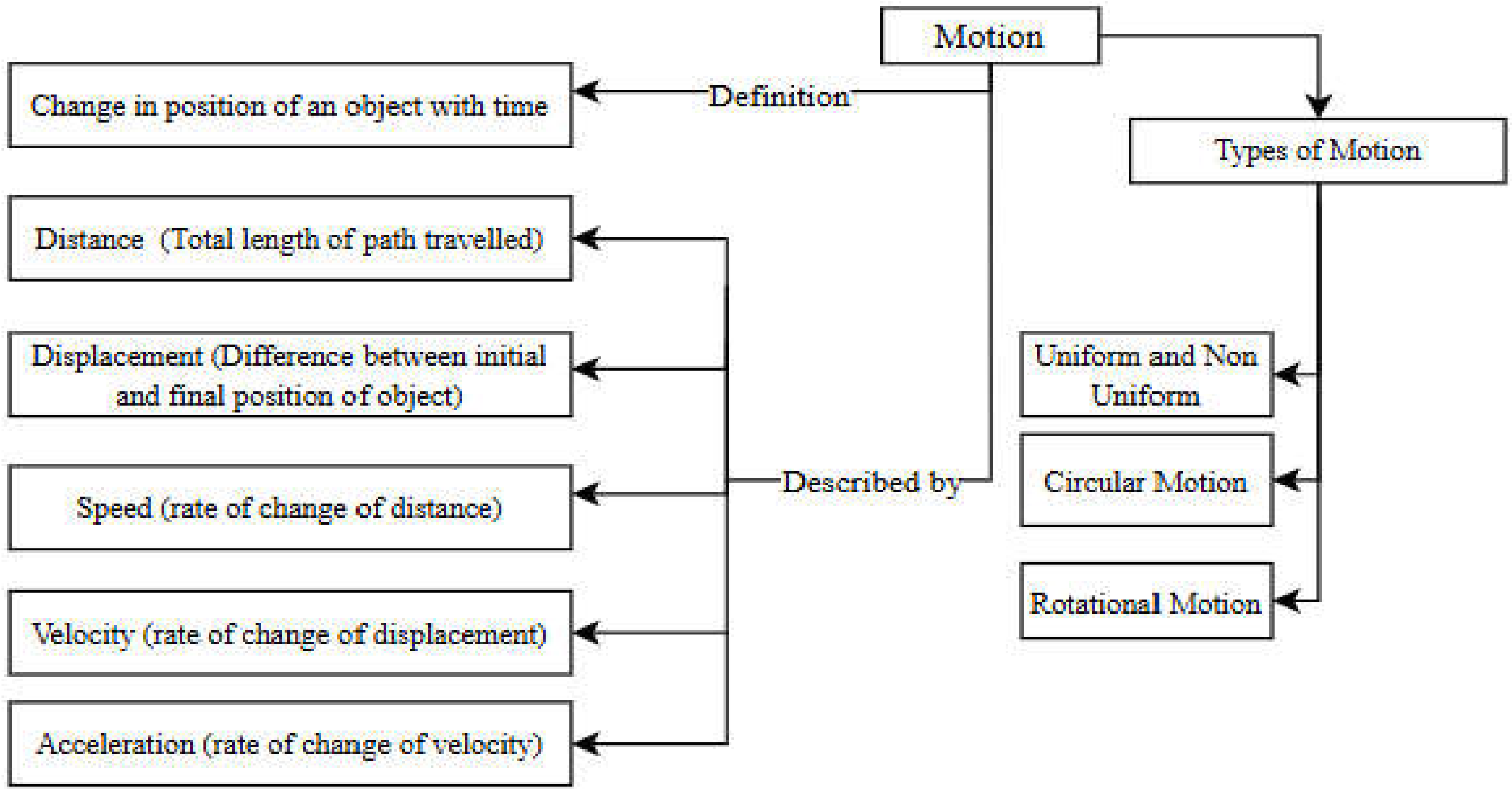
Phase of Lesson	Teacher Initiatives	Student Learning Process/ Activity	Teacher Reflection
	motion **Justification:** The ant can only move along the length of the thread — forward or backward. Its movement is restricted to a single straight line (the tight thread). There is only one degree of freedom (one axis, like the x-axis).	linearly along a narrow, constrained path (the thread). It may move forward or backward but remains on the thread. **Directionality:** It can move only in two possible directions (along the thread either way). **Unique behaviour:** If its direction has to be changed, it must turn around on the same path. Development in concept map may happen as follows: Refer **"Concept map 3"**	
L What have I Learned?	Teacher will encourage the students to analyse the concept map prepared and identify new concepts learnt in this class	Students will examine the developed concept map and identify that they have learnt one dimensional, 2 dimensional and 3-dimensional motion based on the characteristics identified through peer discussion and teacher support	Teacher will ensure that students have attained the second and third learning objectives.
A How will I Apply what I learned?	Teacher will ask students to find more examples on one dimensional, two dimensional and three-dimensional motion.	Concept map is extended by adding new examples by applying the conceptual knowledge of one dimensional, two dimensional, and	The skill of application is assessed to reflect on effectiveness of teaching.

Phase of Lesson	Teacher Initiatives	Student Learning Process/ Activity	Teacher Reflection
	This will enable students to apply the newly learnt types of motion.	three dimensional motion. Development in concept map may happen as follows: Refer **"Concept map 4"**	
Q What new Questions do I have?	Teacher will encourage students to ask doubts/ questions/ clarifications. Teacher may initiate an oral questioning if student participation is found to be inefficient Teacher may clarify/answer the students' questions as follows 1. It is possible. For example, an airplane moving on a runway → 1D; taking off → 2D; flying freely → 3D 2. In our physical, real-world space, motion happens in three spatial dimensions. In advanced physics and mathematics, scientists and mathematicians sometimes describe motion in higher-dimensional spaces for theoretical purposes.	Example questions from students: 1. Can an object transform its motion between three dimensions of motion? 2. Is a higher dimensional motion possible? Can time be considered a dimension of motion?	Skill of questioning and critical thinking skills of students are assessed.

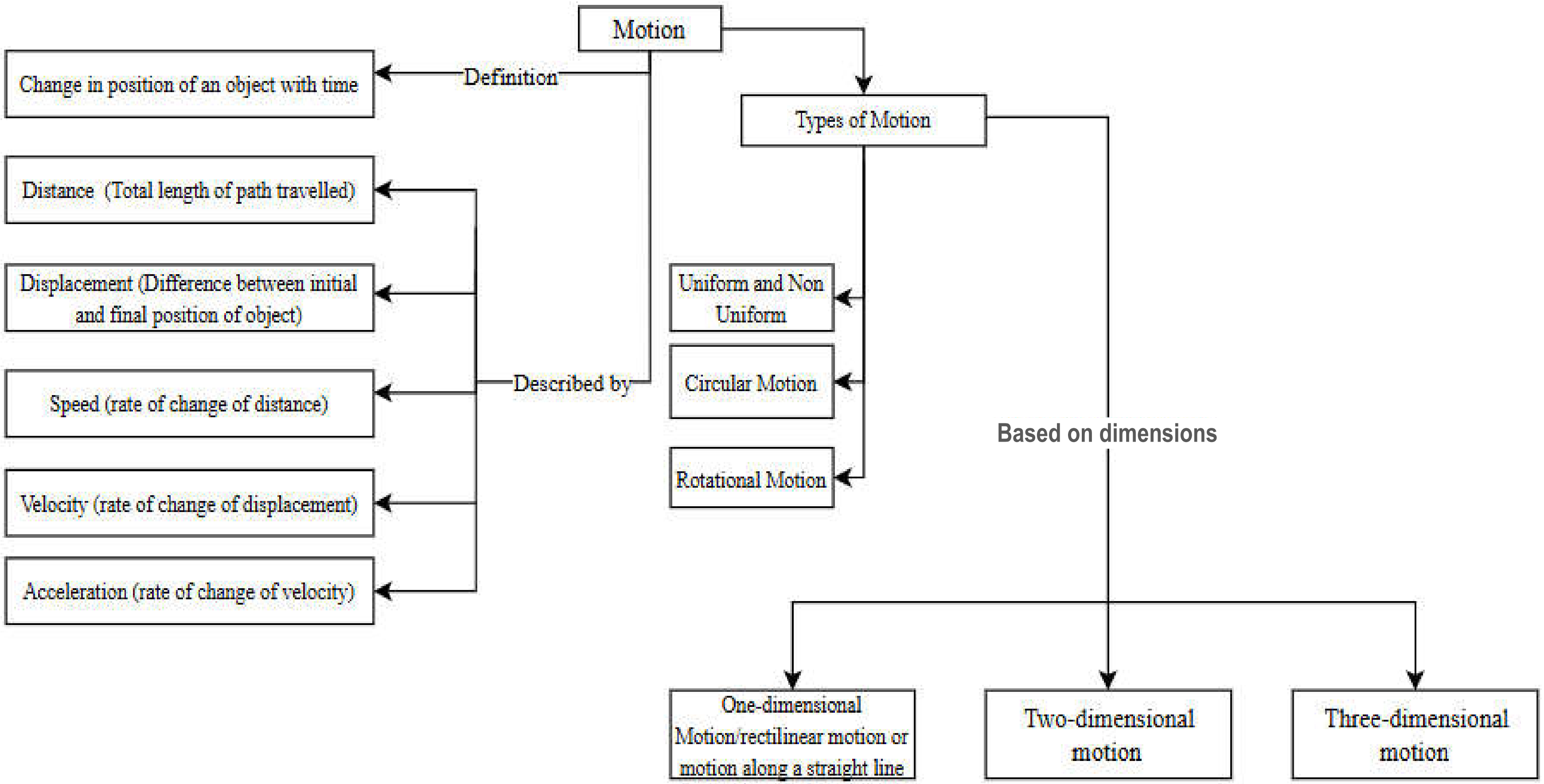
Phase of Lesson	Teacher Initiatives	Student Learning Process/ Activity	Teacher Reflection
	We may use time to measure when and how fast position changes. In advanced theories like relativity, time and space together form 4D space time to describe motion more completely.		
Review, Evaluate and Closure	A quick recap of the lesson is carried out by the teacher. Students are evaluated with a worksheet in which students have to fill in the blanks. A period of 5 minutes was provided for this activity.	Students restate three types of motion along with examples given in the problem as well as the extended examples found in application phase. Students review the hints of the concept map to recall and relate the information to be filled in the blank columns. **Refer Concept map 5.**	Student participation indicates the comprehension of lesson. Concept maps are assessed to check if learning objectives are achieved.

Concept Maps (Examples; Developed through PBL Environment Employed with KWHLAQ Strategy)

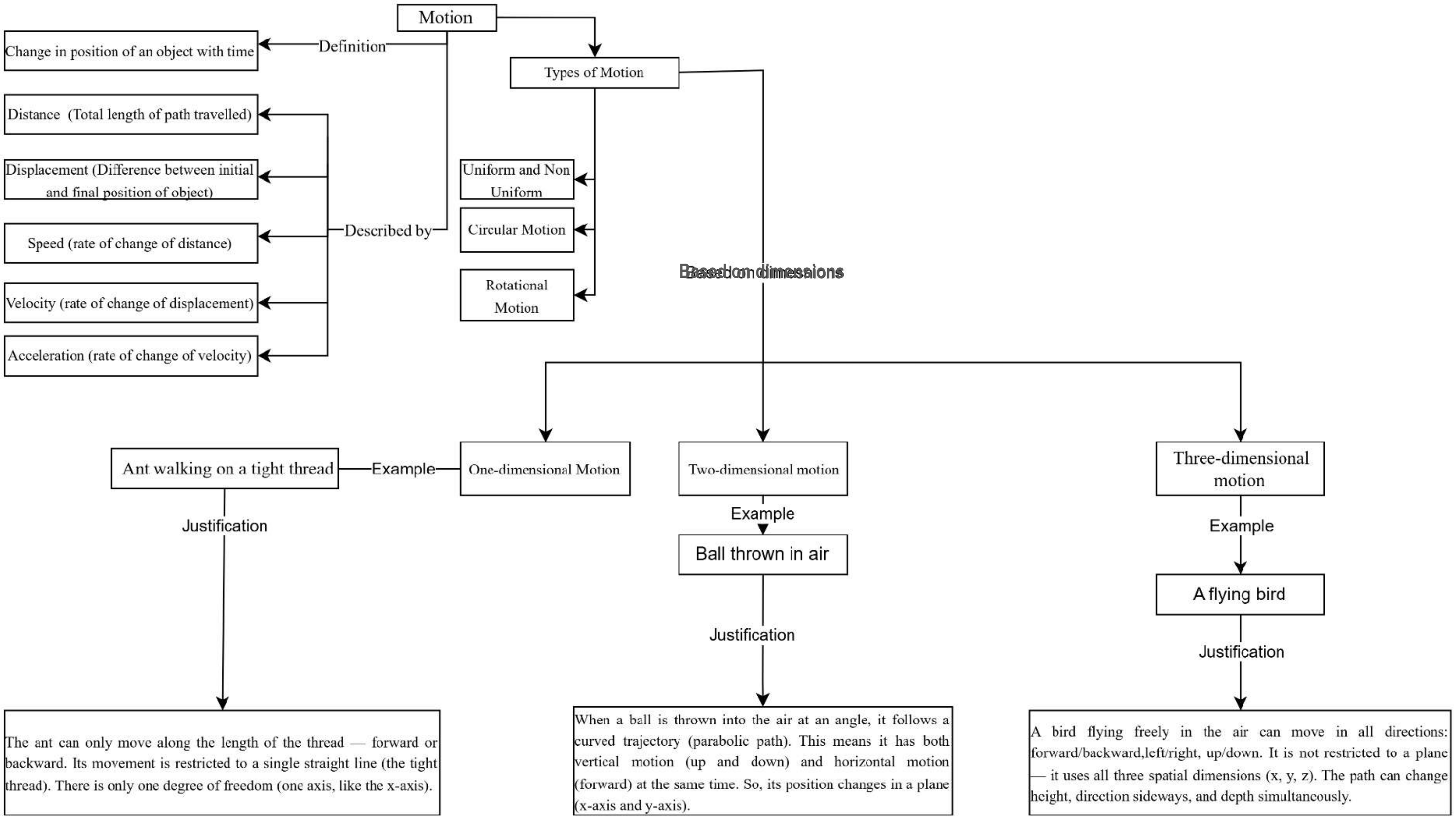
1. Concept Map 1



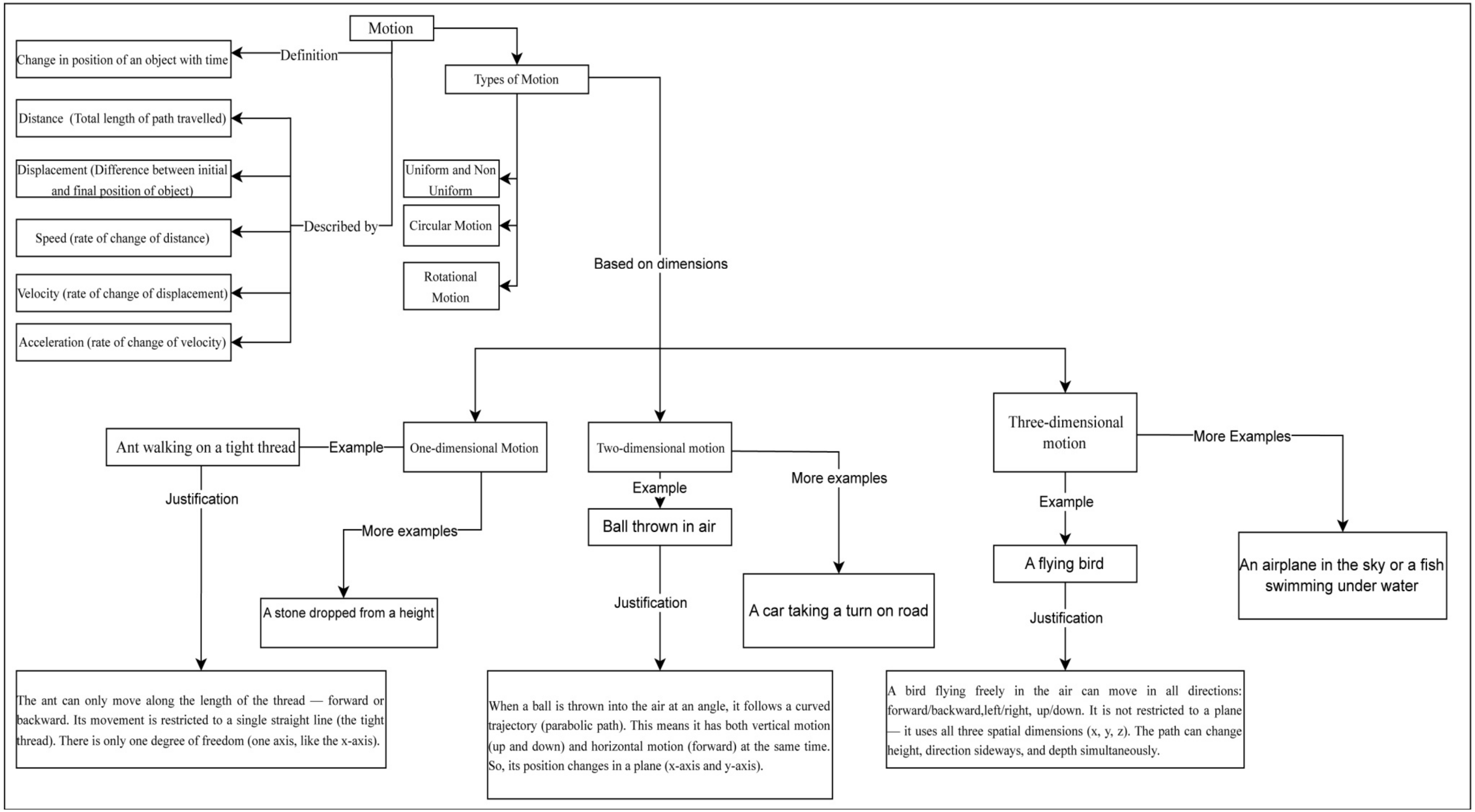
2. Concept Map 2



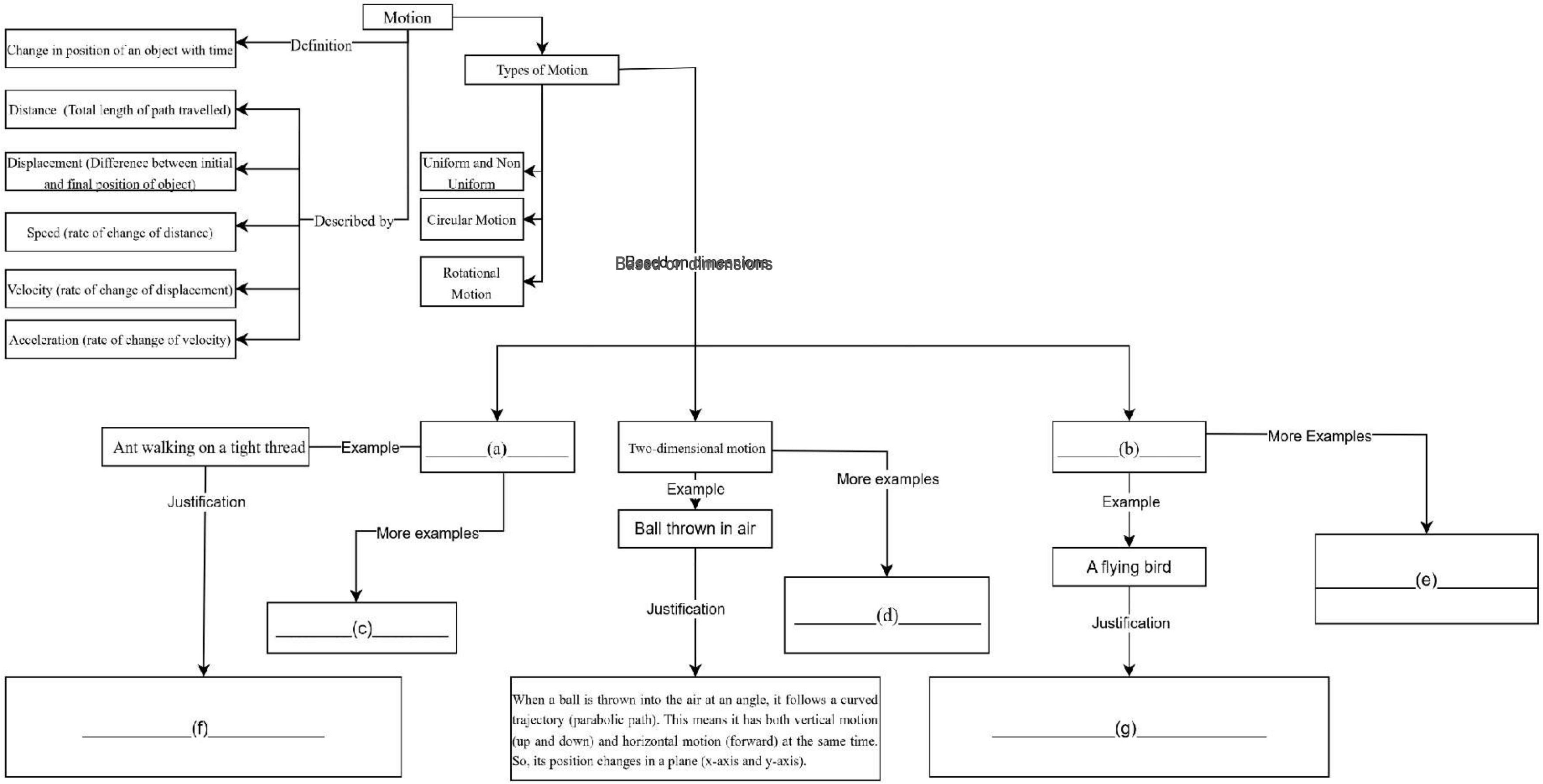
3. Concept Map 3



4. Concept Map 4



5. Concept Map 5



Appendix B2

DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

LESSON TRANSCRIPT BASED ON PROBLEM BASED LEARNING WITHOUT CONCEPT MAPPING STRATEGY

Name of Teacher : Sunil K　　　　Class: 11

Unit : Motion in a Straight Line

Lesson : Types of Motion Based on Dimensions and Rectilinear Motion

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Learning Objectives:

During/at the end of the class, students will be able to

1. Define motion with examples
2. Observe and identify the patterns of motion in different scenarios (ball, bird, ant).
3. Distinguish between one, two, and three-dimensional motion with relevant examples.
4. Define rectilinear motion and explain its characteristics, providing examples.
5. Construct and modify concept maps to organize, visualize, and understand relationships between the concepts of Rectilinear Motion.

Major Concepts / Learning Points:

1. Motion and types of motion (one dimensional, 2 dimensional, 3 dimensional).
2. Direction as a feature of motion; importance of direction in rectilinear motion (ant's movement).

3. Analysis of problem based on KWHLAQ strategy in Problem Based Learning approach

Problem:

Consider the below three cases of motion:

1. A ball thrown in the air
2. A flying bird
3. An ant walking on a tight thread

Analyse the aspects of motion exhibited by each scenario with an aim to understand the significance of recording the direction of an ant as it moves along the string noting down relevant details observed. Compare and contrast the motion of the ball, bird, and ant in terms of their motion pattern, directionality and unique characteristics (if any).

Process Skills:

Observing, analysing, inferring

Pre-requisite Knowledge:

Definition of motion, rate of motion, direction of motion, types of motion (circular, uniform and non-uniform), distance, displacement, speed

Learning Resources:

1. Video resources (three cases of motion mentioned in problem)

Phase of Lesson	Teacher Initiatives	Student Learning process/Activity	Teacher Reflection
Introduction	Teacher will start the class with an activity to list out a few examples of motion from daily life.	Student may list out following examples (or other than these): 1. Walking and running 2. Riding a bicycle 3. Water flowing down a dam 4. A lift moving up/down 5. Rotation and revolution of earth 6. An ant moving forward on a thread 7. A stone dropped from a height	Skill of observation of students is analysed
K What do I think I **know**?	Teacher will define motion as change in position of an object with time. Teacher may ask how can they describe motion. Prior knowledge on motion is asked to be recalled	Students will recall that motion can be explained based on the rate of change of distance (speed), rate of change of displacement (velocity), and rate of change of velocity (acceleration) Students express the definition of motion as follows: "Motion is change in position of an object with time." Physical quantities such as distance (Total length of path travelled), displacement (difference between initial and final position of object), speed (rate	Pre-requisite knowledge of students is assessed. (Class 8 chapter 9 - Motion and Class 9 chapter 3- Laws of Motion) Teacher assess the students through oral questioning

Phase of Lesson	Teacher Initiatives	Student Learning process/Activity	Teacher Reflection
	Teacher asks the difference between speed and velocity	of change of distance), velocity (rate of change of displacement) and acceleration (rate of change of velocity of an object) Students distinguish speed and velocity as follows: speed describes how fast an object moves while velocity describes both speed and direction of motion.	
W **What do I want to learn?**	"What if the direction of motion is not changing? Think from the aspect of speed and velocity" "Pick out the examples (if any) of motion of this type which you have listed out in the beginning of class and also write your own examples (minimum two) in which speed and velocity are same. The teacher will introduce rectilinear motion "Motion of objects along a straight line is known as rectilinear motion" The following problem scenario is provided along	Students will find that speed and velocity will be same if there is no change in direction of motion. Students will list out the following: 1. A lift moving up/down 2. An ant moving forward on a thread 3. A stone dropped from a height 4. A train moving forward on a straight track (new example) 5. Light travelling in a straight line (new example) Students will recognise that all examples of motion they have listed out just now, belong to the type of motion called	Teacher recognises that students have identified the one-dimensional motion as a type of motion through this inquiry Teacher recognises that students have to be introduced to the concept of "Rectilinear Motion" Teacher reflects that students are able to compare and contrast

Phase of Lesson	Teacher Initiatives	Student Learning process/Activity	Teacher Reflection
	with a video resource: “Consider the below three cases of motion: 1. A ball thrown in the air 2. A flying bird 3. An ant walking on a tight thread Analyse the aspects of motion exhibited by each scenario with an aim to understand the significance of recording the direction of an ant as it moves along the string noting down relevant details observed. Compare and contrast the motion of the ball, bird, and ant in terms of their motion pattern, directionality and uniques characteristics (if any).” In todays class we will analyse these three situation comprehensive manner. Teacher will give a hint that there are three cases of motion considering situational difference in problem scenario and that there is a scope of introducing a new set of different types of motion. They are: 1. One-dimensional Motion/rectilinear motion or motion along a straight line 2. Two-dimensional motion	“Rectilinear Motion” Student will observe three cases of motion in the given video resources and identify that the example of an ant walking on a tight thread is rectilinear motion. Students are not able to find out further details of rectilinear motion except the directionality. Students fail (partially or completely) to analyse the aspect of motion exhibited by other two scenarios. Students identify three types of motion viz., 1. One-dimensional Motion/rectilinear motion or motion along a straight line	rectilinear motion with the examples they have listed out. Teacher assesses the students by means of oral questioning on their comprehension on three types of motion

Phase of Lesson	Teacher Initiatives	Student Learning process/Activity	Teacher Reflection
	4. Three-dimensional motion	2. Two-dimensional motion 3. Three-dimensional motion	
H **How do I find out?**	A peer discussion is encouraged by the teacher to analyse the three types of motion in the problem scenario. Teacher will facilitate the discussion reaching a conclusion that 1. Ball thrown in air is an example of 2-dimensional motion **Justification:** When a ball is thrown into the air at an angle, it follows a curved trajectory (parabolic path). This means it has both vertical motion (up and down) and horizontal motion (forward) at the same time. So, its position changes in a plane (x-axis and y-axis). 2. A flying bird is an example for 3-dimensional motion **Justification**: A bird flying freely in the air can move in all directions: forward/backward, left/ right, up/down. It is not restricted to a plane – it uses all three spatial dimensions (x, y, z). The path can change height, direction sideways, and depth simultaneously.	Expected results of discussion are as follows: 1. Ball thrown in air **Motion pattern:** The ball moves upward against gravity until its speed becomes zero at the highest point, then comes back down due to gravity. It follows a curved path (parabolic trajectory). It has varying speed; decreasing while going up, zero at the top, and increasing while coming down. **Directionality:** upward then downward along the same path. **Unique behaviour:** Direction changes at the peak. 2. A flying bird **Motion pattern:** The bird's flight is irregular and self-controlled. It can change speed, altitude, and direction at will. The path can be curved, zig-zag, or linear depending on its purpose.	Engagement and contribution of students in peer discussion is assessed by the teacher and facilitates the students to actively engage in the peer discussion. Inferences drawn by review of problem by students through peer discussion is assessed and modified (if necessary)

Phase of Lesson	Teacher Initiatives	Student Learning process/Activity	Teacher Reflection
	3. An ant walking on a tight thread is an example for one dimensional motion/rectilinear motion **Justification:** The ant can only move along the length of the thread – forward or backward. Its movement is restricted to a single straight line (the tight thread). There is only one degree of freedom (one axis, like the x-axis).	**Directionality:** Continuously changing; not restricted to one axis or plane. **Unique behaviour:** Can hover, ascend, descend, or glide. Uses wings to control lift and direction. 3. Ant walking on a tight thread **Motion pattern:** The ant moves linearly along a narrow, constrained path (the thread). It may move forward or backward but remains on the thread. **Directionality:** It can move only in two possible directions (along the thread either way). **Unique behaviour:** If its direction has to be changed, it must turn around on the same path.	Inferences drawn by review of problem by students through peer discussion is assessed and modified (if necessary)
L **What have I Learned?**	Teacher will encourage the students to analyse the inferences drawn through peer discussion to identify new concepts learnt in this class.	Students will examine the developed concept map and identify that they have learnt one dimensional, 2 dimensional and 3-dimensional motion based on the characteristics identified through peer discussion and teacher support	Teacher will check if the students have attained the second and third learning objectives. Oral questioning is done for this.

Phase of Lesson	Teacher Initiatives	Student Learning process/Activity	Teacher Reflection
A **How will I Apply what I learned?**	Teacher will ask students to find more examples on one dimensional, two dimensional and three-dimensional motion. This will enable students to apply the newly learnt types of motion.	Students review their daily life situation to identify and list out new examples such as: 1. A stone dropped from a height (For one-dimensional motion) 2. A car taking a turn on road (for two-dimensional motion) 3. A fish swimming under water (for three-dimensional motion)	The skill of application is assessed to reflect on effectiveness of teaching.
Q **What new Questions do I have?**	Teacher will encourage students to ask doubts/questions/clarifications. Teacher may initiate an oral questioning if student participation is found to be inefficient Teacher may clarify/answer the students' questions as follows 1. It is possible. For example, an airplane moving on a runway → 1D; taking off → 2D; flying freely → 3d 2. In our physical, real-world space, motion happens in three spatial dimensions. In advanced physics and mathematics, scientists and mathematicians sometimes describe motion in higher-dimensional spaces for theoretical purposes. We may use time to measure when and how fast	Example questions from students: 1. Can an object transform its motion between three dimensions of motion? 2. Is a higher dimensional motion possible?	Skill of questioning and critical thinking skills of students are assessed.

Phase of Lesson	Teacher Initiatives	Student Learning process/Activity	Teacher Reflection
	position changes. In advanced theories like relativity, time and space together form 4D space time to describe motion more completely.	Can time be considered a dimension of motion?	
Review, Evaluate and Closure	A quick recap of the lesson is carried out by the teacher. Students are evaluated with by means of a quiz comprising of 10 questions and additional 5 tie breaker questions. A period of 10 minutes is utilised for conducting quiz.	Students restate three types of motion along with examples given in the problem as well as the extended examples found in application phase. Students actively participate in the quiz activity.	Student participation indicates the comprehension of lesson. Students are evaluated, if they attained the learning objectives of this lesson, through quiz activity.
Quiz Questions (for evaluate phase) 1. Motion of a ball thrown straight up is ___________ motion. (Value point: One dimensional motion) 2. In One dimensional motion, __________ won't change (Value point: Direction) 3. A car cruising at 60 km/h on a twisted road exhibits ___________ motion (Value point: Two-dimensional motion) 4. Can an object have zero displacement but non-zero distance in one-dimensional motion? Give brief justification for your assertion 5. A three-dimensionally moving body can move in how many directions (Value point: Three directions) 6. How two objects in 1D motion on same path can collide without ever turning around? (Value point: if one is			

Phase of Lesson	Teacher Initiatives	Student Learning process/Activity	Teacher Reflection
	faster and behind the other. 7. What extra data do you need to describe 2D motion over 1D motion? (Value point: data on ne more direction) 8. A body in projectile motion will be having ____ (a numerical value) components of velocity (Value point: 2 components (in two directions)) 9. What is the type of motion for Circular motion is? (Scoring point: 2 dimensional) 10. How many directions is needed to explain projectile motion of a ball thrown in air at an angle (Value point: 2 directions (as it is a two-dimensional motion))		

Appendix C1

DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

ACHIEVEMENT TEST IN PHYSICS

DRAFT

SUNIL K	**Dr. MANOJ PRAVEEN G**
Research Scholar	Associate Professor
Department of Education	Department of Education
University of Calicut	University of Calicut

Class	: XI	Max. Marks	: 40
Subject	: Physics	Time	: 1 ½ Hours

(PART 1)

General Instructions:

- This part consists of 10 questions (1-10) of 1 mark each
- Attempt all questions.
- No negative marks for wrong answers

1. When does the average velocity become equal to instantaneous velocity?
2. The speedometer of a vehicle shows ___________
3. The area under velocity -time graph gives ___________
4. A projectile has an acceleration of ___________ in vertical direction and ___________ acceleration in horizontal direction.
5. What is the trajectory (path) followed by a projectile?
6. The slope of position-time graph gives ___________
7. Define uniform motion.
8. Define average acceleration.
9. What do you mean by null vectors or zero vector?
10. A student cycles 3 km North from their home to school in 15 minutes. After school, they cycle back home along the same path, taking 10 minutes due to a favourable wind. Calculate the average velocity for the entire trip.

(PART 2)

General Instructions:

- This part consists of 5 questions (11-15) of 2 marks each
- Attempt all questions.
- No negative marks for wrong answers
- For numerical problems, show your steps clearly.
- Draw diagrams neatly where required.
- Use of calculators is permitted.

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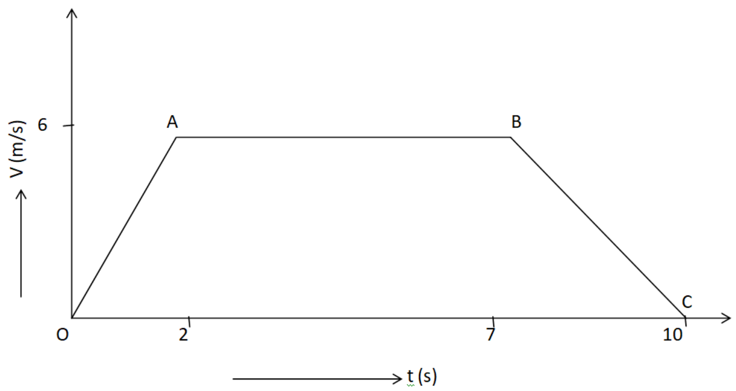
11. State parallelogram law of vector addition.
12. A body moves with uniform motion for 5 seconds, then remains at rest for the next 3 seconds. Sketch the velocity-time graph for this motion and explain the shape of the graph.
13. Velocity – time graph of a body is given below



   a) Which portion of the graph represents uniform retardation?

      (i) OA (ii)AB (iii) BC (iv) OC

   b) Find the displacement in time 2s to 7s.

14. A person walks 4 km east and then 3 km north.
    a) Calculate the total path length.
    b) Calculate the magnitude of the displacement.
15. Design a real-life situation where a scalar quantity and a vector quantity both have the same numerical value but represent different physical meanings. Explain the situation clearly and identify the scalar and vector quantities involved.

(PART 3)

General Instructions:

- This part consists of 4 questions (16-19) of 3 marks each
- Attempt all questions. No negative marks for wrong answers
- For numerical problems, show your steps clearly.
- Draw diagrams neatly where required.
- Use of calculators is permitted.

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16. Is it possible for a body to have zero velocity with a non-zero acceleration. Give an example with explanation.
17. Derive the expression for magnitude of resultant of two vectors by analytical method. Write the expression for direction of resultant vector.
18. A cricket ball is thrown at a speed of 28 m s^{-1} in a direction 30° above the horizontal. Calculate
    (a) the maximum height,
    (b) the time taken by the ball to return to the same level, and
    (c) the distance from the thrower to the point where the ball returns to the same level.
19. Construct a concept map which starts with "Uniform Circular Motion”. Create branches for each of the key concepts Centripetal Force, Centripetal Acceleration, Velocity in Circular Motion, Angular Velocity (ω), Period (T), Frequency (f) and Examples of Uniform Circular Motion.

(PART 4)

General Instructions:

- This part consists of 2 questions (20-21) of 4 marks each
- Attempt all questions. No negative marks for wrong answers
- For numerical problems, show your steps clearly.
- Draw diagrams neatly where required.
- Use of calculators is permitted.

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20. (a) Draw the velocity-time graph of a body with uniform acceleration.
    (b) Using the graph obtain
        (i) Velocity - time relation
        (ii) Displacement -time relation
        (iii) Displacement velocity relation.
21. A car travels 60 km at a speed of 30 km/h and then returns back to the starting point at a speed of 60 km/h.
    a. Calculate the total time taken for the entire journey.
    b. Calculate the average speed of the car for the entire journey.
    c. What is the average velocity for the complete journey? Explain your answer.

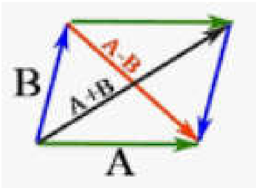
Appendix C2

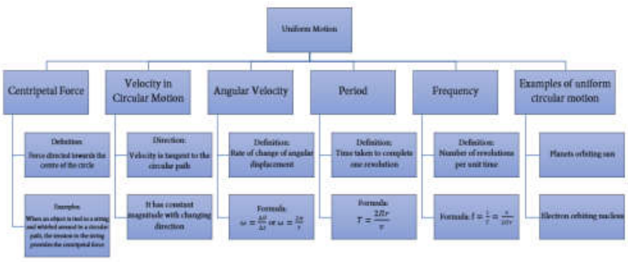
DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

ACHIEVEMENT TEST IN PHYSICS

SCORING KEY (DRAFT)

Q. No	Value Points	Mark Distribution	Total
(PART 1)			
1	The average velocity becomes equal to instantaneous velocity when the body moves with uniform velocity	Analyse and infer - 1	**1**
2	Instantaneous speed	Identify the use - 1	**1**
3	Displacement	Analyse and infer - 1	**1**
4	9.8 m/s^2; Zero	Recognising the acceleration in vertical direction – ½ Recognising the acceleration in horizontal direction – ½	**1**
5	Parabolic path	Identify the trajectory- 1	**1**
6	Velocity	Analyse and infer-1	**1**
7	A body is said to be in uniform motion if it travels equal distances in equal intervals of time.	Appropriate definition-1	**1**
8	Average acceleration is the change in velocity of an object over a specific time interval. OR Average acceleration=(Change in velocity) / (Time taken)	Appropriate definition or formula-1	**1**
9	A vector having zero magnitude is called a zero/null vector.	Appropriate definition-1	**1**
10	Total displacement= 0; Total time= 25 minutes = 1500s ⇒ Average velocity=0 m/s	Data identification – ½ Apply average velocity formula – ½	**1**

Q. No	Value Points	Mark Distribution	Total
(PART 2)			
11	If two vectors are represented in magnitude and direction by the adjacent sides of a parallelogram, then their resultant is given by the diagonal of the parallelogram from the same point 	Appropriate definition- 1 Diagram - 1	**2**
12	From 0 to 5 seconds: The graph is a horizontal line above the time axis, showing constant (uniform) velocity. From 5 to 8 seconds: The graph is a horizontal line along the time axis (velocity = 0), indicating the body is at rest. The graph shows a sudden drop in velocity at 5 seconds.	Sketch velocity time graph – 1 Explanation - 1	**2**
13	a) (iii) BC b) Area under graph from 2s to 7s = Displacement = area of rectangle = 6 x 5 = 30m	Identify portion of uniform retardation – ½ Calculation of displacement – 1 ½	**2**
14	(a) Path length = 4 km + 3 km = 7 km (b) Displacement = $\sqrt{(4^2 + 3^2)} = \sqrt{(16 + 9)} = \sqrt{25}$ = 5 km	Calculation of path length – 1 Calculation of magnitude of displacement - 1	**2**
15	A person walks 5 meters straight in one direction. Scalar Quantity: Distance = 5 m (only magnitude) Vector Quantity: Displacement = 5 m (magnitude and direction) Both have the same numerical value (5) but represent different physical meanings — one is a scalar (distance), and the other is a vector (displacement).	Appropriateness of situation – 1 Identification of scalar and vector quantity – ½ Explanation – ½	**2**

Q. No	Value Points	Mark Distribution	Total
(PART 3)			
16	Yes, e.g., at the highest point of projectile motion (velocity = 0, acceleration = 9.8 m/s² downward). Any valid example with explanation. 1. A ball thrown vertically upwards at the peak, velocity is zero, but acceleration is non-zero.	Assertion – ½ Valid example – 1 ½ Explanation - 1	**3**
17	Derivation of $\mathbf{R} = \sqrt{\mathbf{A^2 + B^2 + 2ABcos\theta}}$, Direction , tan $\boldsymbol{\alpha}$ = $\mathbf{Bsin\theta}$ / ($\mathbf{A+Bcos\theta}$)	Derivation – 2 Expression for direction - 1	**3**
18	a) $H = u^2 \sin^2\theta / 2g$ $H = 28^2 \sin^2 30 / 2 \times 9.8$ H = 10 m b) $T = 2\, u \sin\theta / g$ $T = 2 \times 28 \sin 30 / 9.8$ T = 2.9 s c) $R = u^2 \sin 2\theta / g$ $R = 28^2 \sin 60 / 9.8$ R = 69.28 m	Applying formula – ½ Accuracy in answer – ½ Applying formula – ½ Accuracy in answer – ½ Applying formula – ½ Accuracy in answer – ½	**3**
19		Organisation of branches and content -2 Construction of Concept map - 1	**3**
(PART 4)			
20	a) Straight line graph with positive slope from origin b (i) Velocity – time relation From the graph ,	Drawing the velocity-time graph of a body with uniform acceleration – 1	**4**

Q. No	Value Points	Mark Distribution	Total
	acceleration = slope a = BC / AC a= (v - u) / t v-u = at v = u +at or ($v = v_0 + at$) (ii) Position-time relation Displacement = Area under the graph s = Area of rectangle + Area of triangle s = ut + ½ (v-u) t But v -u = at s = ut + ½ at x t $s = ut + ½ at^2$ or ($s=v_0 t + ½ at^2$) (iii) Position – velocity relation Displacement = Average velocity x time s = ((v + u) / 2) ((v – u) / a) $s = ((v^2 – u^2)/2a)$ $v^2 – u^2 = 2as$ $v^2 = u^2 + 2as$	Deducing Velocity - time relation – 1 Deducing Displacement -time relation – 1 Deducing displacement velocity relation-1	
21	(a) Time for first half = 60 / 30 = 2 hours Time for return = 60 / 60 = 1 hour Total time = 2 + 1 = 3 hours (b) Total distance = 60 km + 60 km = 120 km; Average speed = Total distance / Total time = 120 / 3 = 40 km/h (c) Displacement = 0 (returns to starting point); Average velocity = Displacement / Time = 0 / 3 = 0 km/h Since displacement is zero, average velocity is zero even though the car was moving.	Data identification – 1 Calculation in a) – 1 Calculation in b) – 1 Calculation in c) - 1	**4**

Appendix C3

DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

ACHIEVEMENT TEST IN PHYSICS

FINAL

SUNIL K	**Dr. MANOJ PRAVEEN G**
Research Scholar	Associate Professor
Department of Education	Department of Education
University of Calicut	University of Calicut

Class	: XI	Max. Marks	: 30
Subject	: Physics	Time	: 1 hour

General Instructions:

- Attempt all questions.
- No negative marks for wrong answers
- For numerical problems, show your steps clearly.
- Draw diagrams neatly where required.
- Use of calculators is permitted.

(PART 1)

General Instructions:

- This part consists of 10 questions (1-10) of 1 mark each
- Attempt all questions.
- No negative marks for wrong answers

1. When does the average velocity become equal to instantaneous velocity?
2. The speedometer of a vehicle shows ___________
3. The area under velocity -time graph gives ___________
4. A projectile has an acceleration of ________ in vertical direction and __________ acceleration in horizontal direction
5. What is the trajectory (path) followed by a projectile?
6. The slope of position-time graph gives ___________
7. Define uniform motion.
8. Define average acceleration.
9. What do you mean by null vectors or zero vector?

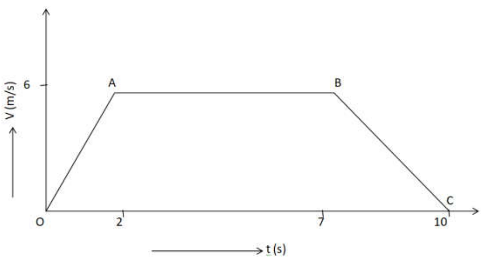
10. A student cycles 3 km North from their home to school in 15 minutes. After school, they cycle back home along the same path, taking 10 minutes due to a favourable wind. Calculate the average velocity for the entire trip.

(PART 2)

General Instructions:

- This part consists of 2 questions (11-12) of 2 marks each
- Attempt all questions.
- No negative marks for wrong answers
- For numerical problems, show your steps clearly.
- Draw diagrams neatly where required.
- Use of calculators is permitted.

11. State parallelogram law of vector addition
12. Velocity – time graph of a body is given below



a) Which portion of the graph represents uniform retardation?
(i) OA (ii) AB (iii) BC (iv) OC

b) Find the displacement in time 2s to 7s.

(PART 3)

General Instructions:

- This part consists of 4 questions (13-16) of 3 marks each
- Attempt all questions.
- No negative marks for wrong answers
- For numerical problems, show your steps clearly.
- Draw diagrams neatly where required.
- Use of calculators is permitted

13. Is it possible for a body to have zero velocity with a non-zero acceleration. Give examples.
14. Derive the expression for magnitude of resultant of two vectors by analytical method. Write the expression for direction of resultant vector.

15. A cricket ball is thrown at a speed of 28 m s^{-1} in a direction 30° above the horizontal. Calculate
    (a) the maximum height,
    (b) the time taken by the ball to return to the same level, and
    (c) the distance from the thrower to the point where the ball returns to the same level.
16. Construct a concept map which starts with "Uniform Circular Motion". Create branches for each of the key concepts Centripetal Force, Centripetal Acceleration, Velocity in Circular Motion, Angular Velocity (ω), Period (T), Frequency (f) and Examples of Uniform Circular Motion.

(PART 4)

General Instructions:

- This part consists of 1 question (17) of 4 marks
- No negative marks for wrong answer
- Draw diagrams/graphs neatly where required.

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17. (a) Draw the velocity-time graph of a body with uniform acceleration .
    (b) Using the graph obtain
        (i) Velocity - time relation
        (ii) Displacement -time relation
        (iii) Displacement velocity relation.

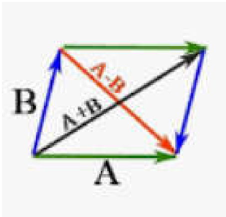
Appendix C4

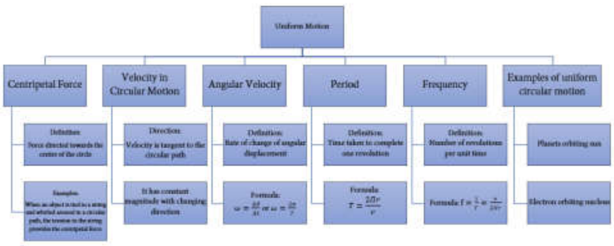
DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

ACHIEVEMENT TEST IN PHYSICS

SCORING KEY (FINAL)

Q. No	Value Points	Mark Distribution	Total
(PART 1)			
1	The average velocity becomes equal to instantaneous velocity when the body moves with uniform velocity	Analyse and infer - 1	**1**
2	Instantaneous speed	Identify the use - 1	**1**
3	Displacement	Analyse and infer - 1	**1**
4	9.8 m/s^2; Zero	Recognising the acceleration in vertical direction – ½ Recognising the acceleration in horizontal direction – ½	**1**
5	Parabolic path	Identify the trajectory - 1	**1**
6	Velocity	Analyse and infer - 1	**1**
7	A body is said to be in uniform motion if it travels equal distances in equal intervals of time.	Appropriate definition - 1	**1**
8	Average acceleration is the change in velocity of an object over a specific time interval. OR Average acceleration = (Change in velocity) / (Time taken)	Appropriate definition or formula - 1	**1**
9	A vector having zero magnitude is called a zero/null vector.	Appropriate definition - 1	**1**
10	Total displacement = 0; Total time = 25 minutes = 1500 s ⇒ Average velocity = 0 m/s	Data identification – ½ Apply average velocity formula – ½	**1**

Q. No	Value Points	Mark Distribution	Total
(PART 2)			
11	If two vectors are represented in magnitude and direction by the adjacent sides of a parallelogram, then their resultant is given by the diagonal of the parallelogram from the same point. 	Appropriate definition – 1 Diagram - 1	**2**
12	c) (iii) BC d) Area under graph from 2s to 7s = Displacement = area of rectangle = 6 x 5 = 30m	Identify portion of uniform retardation – ½ Calculation of displacement – 1 ½	**2**
(PART 3)			
13	Yes, e.g., at the highest point of projectile motion (velocity = 0, acceleration = 9.8 m/s² downward). Any valid example with explanation. 1. A ball thrown vertically upwards at the peak, velocity is zero, but acceleration is non-zero.	Assertion – ½ Valid example – 1 ½ Explanation - 1	**3**
14	Derivation of **R** = √**A² + B² + 2AB cos θ**, Direction , **tan α** = **B sinθ** / (**A**+**B cos θ**)	Derivation – 2 Expression for direction - 1	**3**
15	a) $H = u^2 \sin^2 \theta / 2g$ $H = 28^2 \sin^2 30 / 2 \times 9.8$ $H = 10$ m b) $T = 2 u \sin \theta / g$ $T = 2x\ 28 \sin 30 / 9.8$ $T = 2.9$ s	Applying formula – ½ Accuracy in answer – ½ Applying formula – ½ Accuracy in answer – ½ Applying formula – ½ Accuracy in answer – ½	**3**

Q. No	Value Points	Mark Distribution	Total
	c) $R = u^2 \sin 2\theta / g$ $R = 28^2 \sin 60 / 9.8$ $R = 69.28$ m		
16		Organisation of branches and content -2 Construction of Concept map - 1	**3**
	(PART 4)		
17	a) Straight line graph with positive slope from origin b (i) Velocity – time relation From the graph , acceleration = slope a = BC / AC $a = (v – u) / t$ $v-u = at$ $v = u + at$ or ($v = v_0 + at$) (ii) Position-time relation Displacement = Area under the graph s = Area of rectangle + Area of triangle $s = ut + ½ (v-u) t$ But $v - u = at$ $s = ut + ½ at \times t$ $s = ut + ½ at^2$ or ($s = v_0 t + ½ at^2$) (iii) Position – velocity relation Displacement = Average velocity x time $s = ((v + u) / 2) ((v–u) / a)$ $s = ((v^2 – u^2)/2a)$ $v^2 – u^2 = 2as$ $v^2= u^2+ 2as$	Drawing the velocity-time graph of a body with uniform acceleration – 1 Deducing Velocity - time relation – 1 Deducing Displacement -time relation – 1 Deducing displacement velocity relation -1	**4**

Appendix D1

DEPARTMENT OF EDUCATION
UNIVERSITY OF CALICUT

PHYSICS ATTITUDE SCALE

Kaur, D. & Zhao, Y., 2017

Name	:	Class :
School	:	Date :

Instructions

There are sixty items in this scale. Each, item is followed by live responses ranging from strongly agree (S.A), agree (A), undecided (U.D), disagree (D), and strongly disagree (S.D). Read each item carefully and tick the response, that you feel most appropriate to you. It is necessary to answer all the items there is no time limit and no right or wrong answers. In case you have any difficulty with regard to the instructions please get them clarified before answering the items.

Sl. No	Statements	S.A	A	U.D	D.	S.D
Factor I: Enthusiasm toward Physics						
1	Learning physical phenomena and their description is most enjoyable to me					
2	Studying topics on Physics in greater detail is not worth it					
3	My confidence level increases by doing physics experiment in laboratory					
4	The basic knowledge of physics is useful for everyone					
5	Physics is a boring subject for me					
6	The successful completion of a physics experiment excites me to do other experiments					
7	I will be happy if the practical work in physics is reduced so that I may devote more time in studying theory					
8	I am punctual with physics homework					

Sl. No	Statements	S.A	A	U.D	D.	S.D
9	I wait eagerly for physics period					
10	I discuss physics with my friends					
Factor II: Physics Learning						
11	I feel very pleased and satisfied on answering the questions in physics class					
12	Laboratory work in physics improves individual productiveness					
13	I keep on practicing the problems done in the class till I attain proficiency					
14	I feel stressed in my physics class					
15	Active participation of students in practical and theory classes result in effective understanding of physics					
16	Absence of tutorials in physics is responsible for not getting good marks					
17	I try to correlate the physics problem with daily life situation					
18	I try to focus more on memorizing laws and derivations given in textbook rather than solving physics problems					
19	There are many situations in physics which are difficult to visualize					
20	It is very difficult to succeed in physics exam without cheating					
21	Difficult topics in physics do not interest me					
22	Parents and teacher compel me to study physics					
23	I study physics only when my exams are around					
24	Learning physics is beyond my capability					
Factor III: Physics as a Process						
25	The subject of physics is ever evolving					
26	Physics is not just knowledge but is a process of gaining knowledge					

Sl. No	Statements	S.A	A	U.D	D.	S.D
27	There is no need to further verify the laws already discovered					
28	Scientific knowledge is developing so rapidly that the facts of physics may be found untrue tomorrow					
29	After sometime all the laws of physics will be discovered					
30	The results of physics experiments are very slow					
31	Physics play an important role in the advancement of civilization and society					
32	There is nothing creative about physics; it's about memorizing laws and formulas					
33	Physics has contributed greatly to science and other fields					
34	Physics helps develop person's mind and teaches him to think					
35	Huge infrastructure is needed to build a physics laboratory in order to understand the subject					
Factor IV: Physics Teacher						
36	I am scared of my physics teacher					
37	My physics teacher always overburdens the students with assignments					
38	My physics teacher encourages problem solving					
39	My physics teacher rarely discuss the numerical problems related to a physics topic taught in the class					
40	My physics teacher always comes to the class regularly					
41	My physics teacher does not encourage raising doubts in the class					
42	My physics teacher does not make coherent statements on the topic taught in the class					
43	My physics teacher uses a combination of teaching aids while teaching in the class					

Sl. No	Statements	S.A	A	U.D	D.	S.D
44	My physics teacher often uses a lecture format to teach					
45	My physics teacher spends the necessary amount of time helping me understand physics concepts					
46	My physics teacher does not believe that I am capable of learning physics					
47	My physics teacher often becomes frustrated with me					
48	My physics teacher emphasizes on understanding and not just memorization					
49	I aspire to be a physics teacher					
Factor V: Physics as a Future Vocation						
50	The scope of professional growth as a physicist is very slow					
51	Immense patience and tolerance is required to pursue physics					
52	The progress of a physicist is rather slow					
53	There is lack of job opportunities in physics					
54	Physics is beneficial for those who want to pursue engineering courses					
55	Physicist is a highly dedicated individual working toward the improvement of society					
56	Physics as a vocation lacks creativity					
57	Physicist spends his life by doing physics experiments					
58	Studying physics at a higher level leads to glorious future					
59	Physicists waste public money as all the research work does not have practical applications					
60	Physicist generally remains isolated from society					