Factors impact the Effectiveness of Integrative STEM Education in Vietnamese high school

Abstract

STEM education integrates academic concepts with real-world lessons to connect schools, communities, workplaces, and global organizations. Students apply technology, science, mathematics, and engineering skills in specific contexts. Students learn via experience and address real challenges through interwoven and interrelated communication. STEM education also teaches students soft skills like cooperation, teamwork, problem-solving, creativity, and critical thinking for future career success. STEM education is an interdisciplinary technique integrating with science, technology, engineering, and mathematics has gained global recognition for its potential to prepare students with the skills needed for the modern workforce. In Vietnam as in many other countries there is growing emphasis on integrating STEM education into high school perspective. This approach goal is to provide students with real world learning experiences that bridge the academic disciplines and promote critical thinking, problem solving and the innovation. STEM education in Vietnamese high schools strives for traditional subjects, fostering connections among different fields and emphasis real-world application. From building framework volcanoes to design robotics, student engages in hands-on activities that encourage them to apply their knowledge in the significant way. This integration not only improves the understanding of scientific and mathematics concepts and also it cultivates the skills to need for future careers in STEM. However, the efficiency of integrative the STEM education depends on numerous factors.one of the crucial aspect is the quality of education and the extent to which aligns with the aim of STEM education. Furthermore, the availability of resources, teacher training,

curriculum development and support from educational authorities that plays the significant role in determining the success of STEM program in high school.

In this research we aim to explore the factors that influence the effectiveness of integrative STEM education in Vietnam high schools. By identifying those factors, we can understand better the challenges and the opportunities for enhance the STEM education results and ultimately contribute the development of a skilled and innovative work in Vietnam.

Keywords: Teaching Skills, knowledge, Analysis, STEM Education, Schools, Academic, Creative learning.

Chapter 1

Introduction

This chapter describes the overview of STEM education, role of STEM in improving student performance, STEM education in Vietnam, current status of STEM, education in Vietnam and domain of attitude, knowledge, and application of STEM with a brief explanation of the introduction with respect to the proposed work is presented. Technological businesses are becoming an integral component of our culture in the contemporary world. Utilizing technology, businesses like Apple, Tesla, Facebook, and Netflix have amassed enormous influence. Science thus appears as being essential to the creation of sustainable economic growth and technological innovation. Furthermore, the focus on science and technology is necessary to address global concerns facing humanity in the era of increased computing power and entrepreneurship. One could suggest that "STEM (science, technology, engineering, and mathematics)" domains are more important than ever in context of the critical issues of the day, such as food shortages, health inequalities, and climate change (Ho et al 2020). Vietnam is a nation with lower middle class incomes. It is undergoing a rapid phase of demography and cultural change, characterized by older people in rural regions and rural outmigration. The environment and natural resources have been negatively impacted by industrialization, fast economic expansion, and a population explosion, which has resulted in difficulties with regard to environmental and managing waste. Furthermore, the UN Framework Convention on Climate Change has designated Vietnam as one of the nation's most vulnerable to the impacts of carbon dioxide pollution. The nation is afflicted by a variety of meteorological phenomena, including but not limited to rising sea levels, typhoons, landslides, floods, and droughts (Nguyen et al 2020). It is widely recognized that Vietnamese students are among the most exceptional performers in the scientific portion of the "Programme for International Student Assessment" (PISA). The "Organization for Economic Co-operation and Development" (OECD) released the 2015 PISA results, and among the 72 nations, Vietnamese students' scientific proficiency was rated eighth. Vietnamese students, however, are not very inclined to work in science, engineering, or technology. While the process of globalization necessitates the availability of human resources in the STEM (science, technology, engineering, and mathematics) disciplines, improving students' enthusiasm for pursuing professions in science is crucial to Vietnam's educational objectives for sustainable development (Thi To Khuyen et al 2020).

1.1 STEM Education System

STEM education emphasizes the integration of several courses and their potential applications in real-world scenarios, as opposed to teaching STEM as a collection of discrete subjects. Therefore, it could be said that this is an applied, multidisciplinary method. Curriculum integration includes STEM integration. Curricular integration is a challenging concept that entails much more than just assembling a range of disciplines. A program that emphasizes linkages between these four disciplines and real-world challenges is called STEM education. This method of instruction combines classic scientific and mathematical concepts with Transdisciplinary topics and skills relevant to the twenty-first century. It describes problems that are resolved by using concepts and methods from mathematics and science, engineering collaboration and design methodology, and relevant technology. Fig.1.1 depicts the block diagram of STEM education system.The extensive field of STEM education goes much beyond the subjects included in the acronym. Education in the early years serves as the cornerstone for STEM education. Children are exposed to aspects of the world around them from an early age that may aid in their STEM education (science, technology, engineering, and math). Youngsters who participate in creative, multisensory, hands-on activities are more likely to spontaneously do early STEM research. Early childhood education fosters the development of a child's curiosity, inquisitiveness, critical thinking, and problem-solving skills. Science studies the world around us, including the sun, moon, stars, land, oceans, weather, natural disasters, animals, plants, and food. Possible outcomes are practically unlimited (Khan et al 2022). Today, technology is associated with computers and smartphones, but its origins date back to 19th and early 20th century gadgets like television, radio, microscopes, telegraphs, and compass devices. Engineering addresses transportation, global warming, and creates eco-friendly machinery, appliances, and systems in addition to planning and building buildings. It is a complicated field. Observe the improvements achieved in our everyday lives and homes in the last decade. Math is used in several settings, including grocery stores, banks, tax forms, investment management, and budgeting. All other STEM areas need math. STEM is crucial since it impacts many aspects of everyday life. Below are the four STEM fields:

1. **Science** - Science enhances our knowledge of nature and teaches vital skills like collaboration, research, critical thinking, and experimentation.

2. **Technology** - Technology, which is the synthesis of science and society, includes a wide range of academic disciplines and involves using knowledge, abilities, and computational thinking to improve and fulfil human needs and desires.
3. **Engineering** - This field focuses on using scientific ideas to create tools that are suitable for handling challenges that arise in everyday life.
4. **Mathematics** - By assisting with data interpretation and analysis, problem solving and simplification, risk assessment, and well-informed decision making, mathematical models improve our understanding of the world we live in.

Within these four main categories, there is a vast array of STEM specializations from which students may choose. STEM (science, technology, engineering, and mathematics) courses may be taken at any level, from elementary school to graduate school. Recent studies of educators, parents, and students indicate that there isn't a list of STEM disciplines. In STEM education, several fields and subjects are taught separately as well as a cross-disciplinary approach. At the same time, it builds on prior knowledge and understanding across a wide range of disciplines and acknowledges the critical role that mathematics plays in all aspects of STEM education. This places a lot of emphasis on the relationship between STEM and arts education, which fosters both innovation and creativity.

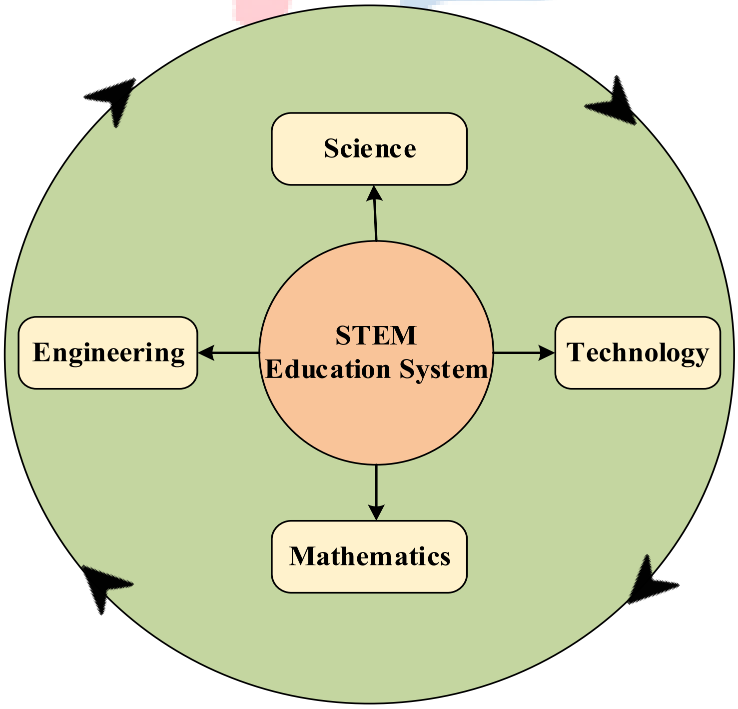

Fig. 1.1 STEM Education System

Children who get a STEM education will be able to use their knowledge and abilities in a range of contexts, from the classroom to the real world, to succeed in their future vocations and lives. The primary objective of STEM education is to assist students in acquiring a diverse range of Essential Qualities that are essential for achieving success in the modern world. Students are anticipated to take part in a variety of activities.

- Creatively resolving issues by utilizing their content knowledge and talents
- Creativity, curiosity, and exploration
- Collaborating with others
- Examining and interpreting
- Making, developing, and experimenting

A rising number of nations' curriculum authorities are starting to adopt larger learning goals, such as teaching pupils on a range of levels of information, skills, attitudes, values, and ethics. This is a positive development for education. In contrast to the more prevalent use of the word "skill," as in "21st century skills," there has been a recent growth in the notion of "competencies" or "competencies" that are important for a satisfying life and well-functioning society.

It is important to highlight the concepts of skills, competences, and competencies as they are currently understood. Generally speaking, the term "skilful" describes the ability to accomplish a job with a certain level of proficiency as opposed to just being able to perform it badly. Using phrases like "skills" or "essential skills" might be seen as reductionist and fall short of capturing the whole range of abilities required to do these duties correctly. As a result, the words "competences" and "competencies" are used more often to characterize the necessary traits for surviving in a complex and interconnected environment. The following eight key STEM competencies are listed:

- Problem solving
- Communication
- Innovative and creativity

- Critical thinking
- Collaboration
- Metacognitive capabilities
- Self-control
- Disciplinary competences

Because these eight fundamental skills are cross-cutting and transversal, they are essential in STEM education. Being successful requires more than just knowledge and skills. To satisfy complicated demands, you may mobilize social and psychological resources (such as talents and attitudes) in an individual setting.

1.2 History of STEM

Researchers at the “National Science Foundation” (NSF) in the United States have been using the acronym STEM education system since 2001. The abbreviation STEM replaced the previous moniker, SMET. All of this occurred during a scientific meeting when educators were rearranging the term SMET to STEM in order to create science-based courses. STEM, a curriculum that instructs pupils in four distinct disciplines, has advanced significantly in terms of its scope and variety of options as compared to prior periods. The term "STEM Education" is still relatively new to Indian educators' academic lexicon. The need for STEM professionals has significantly increased as a result of India's status as one of the world's top producers of scientists and engineers. It is expected that the present trend in the United States where there are more STEM jobs than STEM graduates will continue. According to National scientific Foundation predictions, in the next ten years, math and scientific abilities will be necessary for 80% of new employment (Singla et al 2023).

They possess exceptional potential in creativity, invention, and problem-solving, but their progress has been hampered by the outdated educational model that prioritized exams. So, look to the STEM players to meet this requirement. As a way to increase students' and recent graduates' employability and skill development, STEM education has taken on a major role in India's educational system. There are now many, disorganized, and inconsistent commercial and government initiatives in India that focus on advancing and integrating STEM concepts into elementary, secondary, and postsecondary education. The fact that a sizable portion of Indian youth is pursuing STEM degrees has to be acknowledged. The global backdrop has made STEM education and learning in India more of a need than a wish list. There is a great deal of STEM-related development occurring in India:

- New approach to teaching STEM and hands-on learning are begin experimented with using Information and Communication Technology (ICT) and classroom platforms.
- A lot of STEM organizations and educational institutions are making an effort to set up STEM centers and tinkering research centers using cutting-edge technology like augmented reality and virtual reality.

- Education establishments are receiving support to modernize their library facilities, which includes installing gamification, language labs, assessment tools, and learning management systems.
- A new wave of 'entry level' coding devices is making it possible for schools to expose students to STEM courses and basic coding.
- India is the second most populous nation in the world; thus, it is imperative that the government and other education providers collaborate to assist India reap the advantages of STEM education.

When India attained independence in 1947, its founding fathers gave the advancement of science and technology top importance. The increasing need for scientists and engineers in India's expanding industries led to the establishment of more institutions. There was a tough struggle for admission because of the increased competition for spots at these elite universities as the population increased. Since then, institutions and their affiliated coaching programs have been more important in helping students succeed on these difficult entrance tests. Rather than serving as a platform for novel concepts and inventive approaches, these educational establishments have instead evolved into hubs for individuals who excel in demanding assessments while possessing the capacity for creative or unconventional thinking. The nation now has a highly competent technical workforce that can get the job done, but it falls short of expectations when it comes to originality and innovation. India made the decision to adopt STEM-based education at the same time as it gained popularity in the United State (US) as a way to bolster the STEM workforce there. Because future trends indicate that those pursuing careers in STEM subjects would have the best employment in the world, the Indian government decided to launch this program. Early identification of potential scientific career prospects is critical for developing the future generation of scientists. Opportunities for research training should be available to Indian middle and high school students. India, the country that produces the most research and development (R&D) worldwide, may take a cue from the US [reference (3)].

1.3 STEM's contribution to raising student achievement

Preparation for high school, in particular, is seen to be crucial in influencing kids' choices to pursue college courses and goals for STEM jobs, drawing them into STEM disciplines and vocations, and providing the foundational math and scientific instruction. Therefore, it is believed that STEM high schools allow kids to study mathematics and science at far higher levels than they might have in a traditional high school, allowing them to pursue more advanced math and scientific degrees. This is due to their emphasis on the enrolment and performance in math and science courses. It is possible that girls and underrepresented minorities will be affected differently by STEM high schools compared to whites and men. The years leading up to and including secondary education (spanning from elementary school to the first many years of college) are especially important for females in the "leaky pipeline" phenomenon, which is the steady departure of females from STEM fields of study. The disparity between male and female students' choices in advanced scientific and mathematics courses in high school contributes significantly to the gender gap in science, which starts off reasonable in the middle grades and grows as students proceed through the educational system. Female students' performance can be impacted by STEM schools in a number of ways.

On the one hand, if rigorous science and math curriculum at Female performance in STEM high schools is more positively impacted than male performance, then STEM schools could potentially close the gender gap and benefit women. However, women are more vulnerable than men to a number of educational variables, which might make STEM fields unwelcoming to them. Differential teacher expectations, whole group and guided instruction, the underrepresentation of female instructors, and the underrepresentation of female classmates are among the educational characteristics was linked to the racial disparity in “STEM” achievement. The same reasons that account for the gender gap also largely drive the gaps for underrepresented minorities in STEM fields. However, socioeconomic barriers like poor parental education and money also significantly contribute to minorities' limited access to STEM resources and educational opportunities. One of the most significant indicators of earning a college degree in a STEM field is the intellectual background received by pupils of different racial backgrounds in high school, particularly the coursework completed in sophisticated mathematics and science. This is also true for female students. School atmosphere is important, just as it is for women. A higher proportion of minority students, instructors of the same race, and other elements that impact students' and teachers' experiences and interactions might influence minority students' interest in and perseverance in STEM. Evidence has demonstrated that scientific inquiry education and solving issues play a vital role in the integration of STEM subjects. Typically, students do group research, finish projects, assess theories, and develop, plan, and carry out methods and solutions. Multimedia could be used to create and improve fluidity in a variety of contexts. It gives students a goal, a context, ideas for the future, and it can additionally link a number of students to the outside world. A different route to knowledge, multimedia promotes the development of intellectual vocabulary when used well to apply new concepts or provide a weak learner background information or context. This is fair to students who struggle with learning and are unable to rely on previous experiences. Even if they may not be able to read a formal paper, children can still learn more about topics they are interested in and get context by using digital documents, concepts, and principles (Chaudhary et al 2020).

1.4 STEM Education in Vietnam

Lower-middle income countries include Vietnam. The rapid economic and social development of the area is evident via the occurrence of rural emigration and the simultaneous growth of rural communities. Rapid economic expansion, industrialization, the environmental impact of rising population has proved detrimental to biodiversity, making waste and pollution control difficult. Moreover, Vietnam is very vulnerable to the impacts of global warming, according to the Intergovernmental Panel on Climate Change. Sea level rise, typhoons, landslides, floods, droughts, and other weather-related occurrences are among the problems faced by the nation. With student performance above that of several OECD nations, Vietnam received a high ranking in the “Program for International Student Assessment (PISA)”. Vietnam does well in general education when it comes to learning attainment and coverage, although most public and private schools use a teacher-cantered approach and heavily depend on textbooks. This method hinders pupils from benefiting as much as they might from contextualized learning (Chen et al 2021).

So, the following queries come out: in what ways can Vietnam's educational system help students advance their professional and academic skills and, in the end, help ensure that sustainable development is achieved through high-quality education.

With funding from the Asian Development Bank, the Department of Instruction and Development has implemented STEM education in high schools under the Second Secondary Education Sector Development Program II (SESDPII). The SESDPII established the following goals for STEM education:

- To improve students' overall education;
- To enhance students' understanding and proficiency in STEM subjects
- In order to enhance pupils' intellectual and interpersonal abilities, like collaboration, intellectual curiosity, problem-solving, creativity, and critical thinking;
- In order to create a link between communities and schools
- To guide pupils' professional advancement;
- In preparation for the advent of Industry 4.0.

Promoting scientific education that integrates math, science, engineering, and technology is the program's main objective. Members from educational establishments in both northwest and southern Vietnam comprise the national STEM research group, which was established under the project. All high school teachers nationwide have access to the experimental results of the organization about interdisciplinary collaboration, collaborative ideas, and innovative teaching approaches that combine STEM. The curriculum provides specialized instruction in STEM concepts, comprehensive structures, instructional methods for both younger and higher secondary schools, and the significance of STEM instruction in fostering growth to school administrators, educational policymakers, and implementers. The training is conducted with the help of the STEM study team, and participants include scholars from various educational institutes around the country. The program invites educators to work together to create STEM lesson plans and themes and to begin experimenting with STEM instruction in classrooms.

1.5 STEM Literacy Elements

The term "STEM literacy" refers to a comprehensive collection of abilities, knowledge, and competences that allow persons to comprehend and interact with ideas and activities in the fields of STEM education system in an effective manner. Fig. 1.2 displays the components of STEM literacy (Falloon et al 2020).

- **Capacity to recognize STEM issues:** Referring to the aptitude for formulating STEM related issues or inquiries within a practical setting and seeking solutions to these problems or inquiries through the implementation of a STEM education approach, as well as the capacity to identify pertinent evidence, firsthand witnesses, or information required to address the concerns or queries.
- **The ability to pursue new information:** This applies to the capacity to establish a specific set of queries that will guide the search for solutions, and also the ability to efficiently and dependably combine information from different sources.
- **Implementing STEM concepts:** the capacity to apply "scientific, technical, engineering, and mathematical" ideas and procedures to circumstances that occur in everyday life while taking into consideration any potential effects that could be triggered by such conditions.

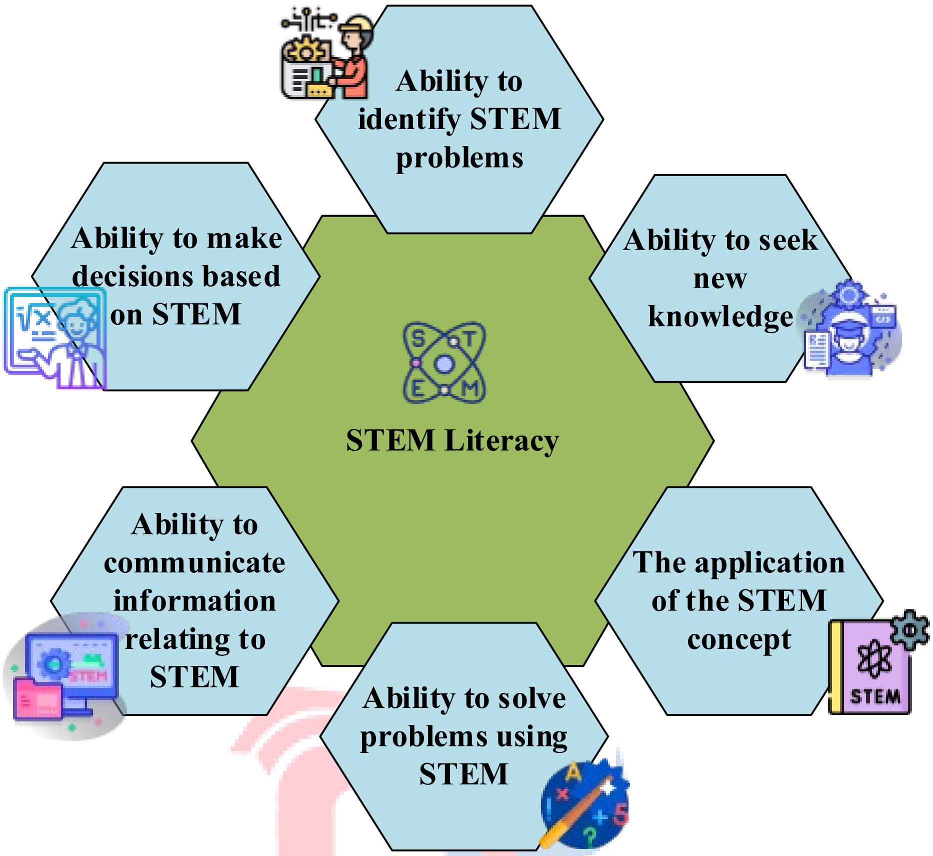

Fig. 1.2 Components of STEM literacy

- **Ability to solve problems using STEM:** In order to the capability of selecting appropriate scientific, technical, engineering, and mathematical instruments and methods in order to assist in the resolution of difficult issues using complex thinking abilities.
- **Ability to communicate information relating to STEM:** refers to the capacity for excellently communicate and comprehend facts and knowledge pertaining to the fields of science, technology, innovation, and engineering.
- **The willingness to make choices based on STEM:** refers to the capacity to define, criticize, remark on, and variety judgments on complicated challenges that are prevalent in the current world through the use of scientific, technical, engineering, and mathematical principles and procedures.

1.6 Integrated STEM Education

The principle of constructivism serves as the foundation for the learning and teaching technique known as integrated STEM education. Exploratory education is an instructional strategy that includes students participating in worthwhile learning experiences that include research or creative endeavours that integrate and apply information and/or abilities in the fields of "science, technology, engineering, and mathematics". Situational education is the integration of STEM concepts and abilities, such as "engineering design, scientific inquiry, technical literacy, and logical thinking, within an interactive environment of practices. This is what is meant by an integrated STEM teaching method. According to the approach, the majority of the material that is associated with STEM is based on situated cognition theory. This theory asserts that it is just as important to understand how knowledge and skills are used as it is to acquire them. Protection provides a suitable setting and platform for teachers to include integrated STEM education sessions or use related strategies. Design for engineering is a crucial element in the integration of STEM topics because it enables students to discover connections between different disciplines and provides a systematic approach to solving issues. Students are able to acquire new understanding of science and mathematics as a result of the educational process that students undergo while applying the technical design method's stages. Fig.1.3 illustrates the STEM Integration architecture (Costa et al 2022).

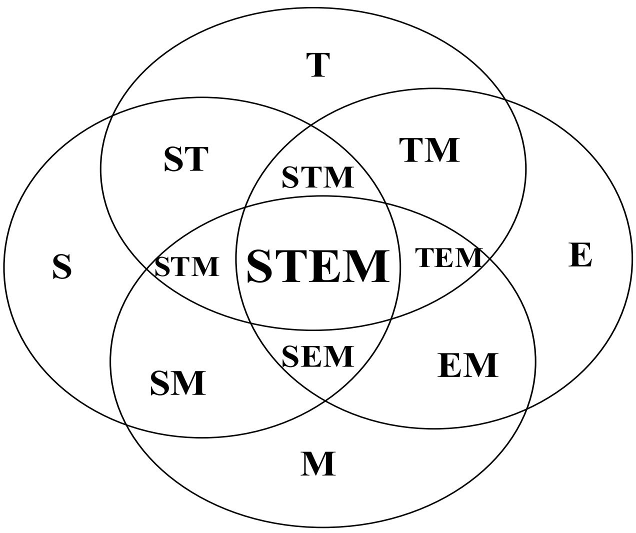

Fig. 1.3 STEM Integration

1.6.1 Types of integrated STEM approaches

The STEM integrated methods attempts to integrate different fields efficiently to make learning more efficient and interesting. Types of integrated approach represented in below several integrated STEM approach types are follows: [Integrated STEM Approaches and Associated Outcomes of K-12 Student Learning: A Systematic Review]

1.6.1.1 Problem-based learning

Students are actively engaged in the process of addressing practical challenges are addressed by using problem-based learning, a method that necessitates the practical application of information from a variety of STEM education approach. Students are encouraged to understand and deal with difficult issue through the use of this method, which places an emphasis on critical thinking, collaboration, and the practical application of skills.

1.6.1.2 Project based learning

Including ideas from STEM domains in order to generate a desired outcome, which requires them to work on projects for a long length of time. Students participate give the opportunity to engage in deep exploration of concepts while simultaneously expanding their practical skills and knowledge through persistent inquiry and project creation.

1.6.1.3 Inquiry-based learning

A range of STEM fields are frequently included into the educational purpose through the educational approach, which improve the student performance crate new understanding of the questions. By enhancing the student’s performance to evaluating and exploring, this method fosters curiosity, calculation skills, and a deep understating of the scientific issue.

1.6.1.4 Design-based learning

To design problem while engaging the design-based learning, which emphasizes the engineering and design processes, by utilizing the concept of STEM can come up with the solutions. Testing and improving the products which also accruing the core STEM knowledge, this method fosters creativity, problem-solving, and iterative learning and development by engaging in the process of development.

1.6.1.5 Transdisciplinary approach

By erasing traditional barriers between disciplines, the Transdisciplinary Approach facilitates the coordinated study of multiple STEM domains, typically in relation to a common topic or problem. Students can recognize the interrelationships and practical uses of their learning across many disciplines due to the implementation of this approach, which promotes comprehensive understanding and interconnected thinking.

1.6.1.6 Scenario-based learning

Situation based Learning is a research-based approach to education that places students in real-world or hypothetical circumstances and asks them to apply what they know about STEM fields to solve problems that are unique to those situations. This technique enhances the relevance and engagement of learning by emphasizing situational learning and actual use of skills. This is achieved by immersing learning in real-life situations.

1.6.1.7 Collaborative learning

To solve the difficult problem and finishing the assignments, learning engage in cooperative education, work together as a groups which solve the problems and difficulties. This approach promotes the cooperative learning and improves the student's capacity to work together, tackle the problem and interact from many problems.

1.6.1.8 Flipped classroom

Pupils are required to view videos or browse materials independently during the projects the problem and practical work in class, as per the "Flipped Classroom" philosphy. This method maximizes the effectiveness of direct teaching and hands-on application during instructional periods. This strategy also enables instructors to offer more individualized support and direction during discussions.

1.6.1.9 Gamification

The incorporation of features and principles from the design of games has been referred as gamification in the field of STEM education system. Gamification is a method that's aim to improve the learning process by providing them with assignments that are both the engaging and competitive. To amplify the student engagement and tenacity, by converting the learning process into an interesting and invigorating experience through the utilization of rewards, challenges, and competitive.

1.6.1.10 STEM Labs and makerspaces

Students are afforded the chance to engage in experiential STEM learning opportunities through practical experiments, activities, and projects, within institutions designated as STEM Laboratories and Makerspaces. These areas are equipped with the necessary tools and supplies. Thereby promoting experimentation, innovation, and the development of practical abilities, Students are provided with the chance to investigate and produce within a specific environment that is supportive and abundant in resources.

1.6.1.11 Integrated curriculum

That the integration of STEM topics and is concentrated on key themes or abstract ideas, the uses of mixed curriculum allows for the creation of a lesson plan. This approach clarifies the interconnections among several disciplines. To skillfully apply that knowledge in various situations and to develop a thorough grasp of STEM ideas this approach encourages students. In comprehending the importance and interrelation of the knowledge they are gaining, it assists students.

1.6.1.12 Field-based learning

Students apply STEM principles in real-world situations through field-based learning, which incorporates educational activities that take place outside of the classroom. Examples of field excursions, internships, and community projects are examples of learning experiences that fall under this category. Through the use of this strategy, classroom learning is connected with practical applications and vocations, so giving students with genuine experiences that strengthen their grasp of STEM areas and increase their interest in these fields. Field-based learning (FBL) in STEM education is an experiential teaching approach that extends learning beyond the traditional classroom by engaging students in real-world environments.

It enables learners to directly observe, investigate, and apply scientific, technological, engineering, and mathematical concepts in authentic contexts, thereby strengthening the connection between theory and practice. In STEM education, field-based learning involves activities such as field surveys, laboratory visits, industrial internships, environmental studies, geological fieldwork, agricultural experiments, and technology-based site explorations. These experiences promote inquiry-based learning, where students collect real data, analyze observations, use scientific tools, and solve practical problems.

As a result, students develop deeper conceptual understanding, critical thinking, and problem-solving skills. Field-based learning also enhances interdisciplinary integration in STEM by allowing students to see how science, mathematics, engineering, and technology interact in real-life applications. For example, studying ecosystems combines biology, chemistry, data analysis, and modeling, while engineering field projects integrate physics, mathematics, and technology design. This holistic exposure improves learner motivation, creativity, and collaboration. Furthermore, FBL supports skill development essential for future careers, including teamwork, communication, data interpretation, and decision-making. It also increases student engagement and retention by making learning meaningful and context-driven. With the integration of digital tools such as sensors, mobile devices, drones, and GIS technologies, modern field-based learning has become more adaptive, scalable, and aligned with next-generation STEM education goals. Overall, field-based learning is a powerful pedagogical strategy in STEM education that bridges academic knowledge with real-world practice, fostering experiential learning and preparing students for complex, real-world challenges.

1.7 How STEM Education Helpful

Schools in particular now have a more difficult role to play in society. It is believed that the younger generation would be emotionally and socially resilient as well as knowledgeable about the newest technologies. But the primary goal of education is academic achievement, which is determined by earning high scores on board examinations. Since our testing system solely evaluates the cognitive portion of learning, schools do not prioritize helping children improve their talents. In our educational system, assessments seldom encourage originality or creativity. People have a very curious intellect and are naturally curious beings. A little youngster is always asking, "Why?" to things. However, rather than encouraging inquiries, we reward answers in schools. Studies reveal that a pre-schooler asks his or her parent 100 questions on average every day. By middle school, the child stops asking questions since our educational system doesn't support them sufficiently. The child's questioning has ended because of this method. According to studies in educational psychology and neuroscience of learning, a kid's brain changes as they acquire a new ability, but those changes reverse if the youngster stops practicing it (McComas et al 2020).

The Sustainable Development Goal 4.7 of United Nations Educational, Scientific and Cultural Organization (UNESCO), which states that by 2030, all students should have the expertise and STEM education will also contribute to the development of the skills and knowledge required to advance sustainable development, such as environmentally friendly and ethical living, equal rights for all people, and the advancement of the values of harmony and nonviolence, citizenship across borders, and a knowledge and awareness of cultural diversity. In order to accomplish this goal, the Mahatma Gandhi Institute of Education for Peace (MGIEP) focuses on teaching people how to create peaceful, sustainable communities everywhere. Transforming Education for Humanity, Building Emotional Learning for Education 2030 is its stated goal. The goal of formal education is to help learners develop their social and emotional competencies. The Institute envisions a "whole brain approach to education" based on learning neuroscience research, emphasizing the development of students' intellectual and emotional intelligence to prepare them to create more peaceful and sustainable societies (Rethinking Schooling, annual Report of UNESCO MGIEP).

1.8 STEM Policy

Understanding the policy context in which comprehensive STEM instruction is being promoted is essential. The different approaches are a direct response to governmental mandates that have arisen inside the United States and prioritize the need of tackling pressing issues, such as the demand for a STEM workforce. Policy considerations are dominated by the premise that meeting the needs of the STEM workforce is critical for addressing important issues like as health, energy, the natural world, national security, and international growth in order to maintain continued national prosperity. The pace of growth in STEM professions is outpacing that of non-STEM employment, potentially resulting in a deficit of up to 3.5 million new STEM workers in the US by 2025. STEM workforce arguments are used globally to develop new policies and efforts for STEM education. Beyond the lack of STEM personnel, policy papers do not go into detail concerning the demands of the STEM workforce. In order to effectively respond to policy demands regarding the STEM workforce, it is essential to have a deeper comprehension of the specific knowledge and abilities that students require when seeking excelling as STEM professionals.

Concerns of a global and American "creativity crisis" are more particular to the demands of the STEM sector. STEM businesses need a workforce that has robust STEM knowledge and abilities, as well as the capacity to thrive in the global economy by exhibiting robust 21st period qualities such as serious rational, statement, cooperation, and inventiveness. As automation and artificial intelligence in the workplace continue to rise at an accelerated rate, a World Economic Forum poll projects that over approximately 65% of current kindergarten students will ultimately pursue careers that have not yet been created.

Therefore, it is insufficient to anticipate that our kids would only acquire disconnected facts and information. Instead of seeing students as passive recipients of information, it is more beneficial to engage them in the active process of constructing knowledge.

The profound comprehension of subject matter acquired via the process of constructing knowledge serves as the foundation for students to use twenty-first century abilities in order to generate, examine, assess, innovate, and tackle real-world issues. The current STEM policy discourse is less likely to include arguments fundamental problems with fair schooling and impoverish alleviation in emerging nations should be addressed by

Comprehensive STEM instruction, as well as promote increased STEM literacy and awareness. Some scientific instructors consider teaching STEM primarily from a workforce perspective to be harmful.

1.9 Training

In the technologically advanced and competitive world of today, change is unavoidable. They are inevitable but with ongoing and creative training, we may modify and adapt to such changes. Any society's foundation is education, and teachers are the most important means of imparting information. Thus, the role of teachers and teacher preparation programs in the educational system is crucial.

The process of being aware of and acquiring the necessary abilities to carry out a specific set of tasks associated with a work, or the whole job, is known as training. It encompasses not only a method for learning the technical components of a work but also a procedure for familiarizing oneself with the social and emotional health necessary for a job effectively done. Thus, training contributes to a positive shift in an employee's knowledge, skills, and attitude, or KSA. Organizations must realize that training should aim to enhance a person's whole personality in addition to helping them acquire the necessary skills. An intelligent and talented individual wouldn't put in any effort unless he was driven and eager to do so. Therefore, training needs to focus on a person's social and emotional intelligence in addition to their IQ (Bordia et al 2018).

Training is any action that aids a person in acquiring and enhancing the abilities necessary to do a job, either now or in the future. Green (2004) elaborates further, stating that a training program is an endeavor to improve people's knowledge, abilities, attitudes, and conduct in order to enable them to do their assignment. Training as an ongoing process that helps people does their jobs more effectively rather than a one-time occurrence. Training as a planned, structured activity that improves trainees' abilities, competencies, and knowledge to carry out a task successfully and efficiently. An organization's requirement for a training department is felt whenever there is a demand for learning anything new. According to him, training is the development of an understanding in individuals that enables them to learn and adopt new behaviors. Those workers may pick up knowledge via formal training programs set up by firms, e-learning courses, and on-the-job training. Effectively designed and carried out training makes participants feel sparkles rather than nervousness. In order to bring about a positive change in the knowledge, skills, attitudes, behavior, and competencies of its recipients and enable them to perform better in their jobs, training should be a well-planned and designed activity with specific objectives. The architecture of training need identification is presented in Fig. 1.5.

Fig. 1.5 Training needs identification

The identification of the organization's, environments, and person's training requirements is the first stage in the training process. The school is the most significant institution in the area of education, with the main goal being to provide all students with a high-quality education. This goal makes having qualified instructors in a classroom necessary. This is made worse by the modern technological environment, which highlights the need for instructors who are not only highly qualified but also up to current on technology. The government and education experts can better identify the skill sets required of school instructors with the aid of this need research. The deficiency of these talents results in individual or collective need.

The educationists are able to construct the training design with the assistance of this need assessment. The training design is a blueprint that specifies the goals that trainees are expected to accomplish once they have completed the training program. By establishing such goals, it is possible to facilitate the development of a control system that is comprised of standards that trainees are expected to achieve in order to evaluate the efficiency of the training.

A thorough planning and organization of some key issues, such as the readiness of the trainees for the training, the identification of the best trainers, the elaborated content of the training, the evaluation of the best and most suitable training methods and techniques, and the preparation of training materials, both in print and audio-visual formats, is the next step.

Another factor that contributes to the smooth flow of training sessions is the availability of convenient training schedules and locations. Because of this, it is very necessary to make all of the necessary technical preparations for the training in advance in order to ensure that the program is carried out without interruption. The process of evaluating training is a control mechanism that determines whether or not all of the efforts that have been put into training are heading in the proper direction. This can be done at four levels – immediate reactions of the stakeholders (principals of schools, teachers as well as the trainers), acquiring achievements of the trainees (new technology or new styles to teach), behavioral changes in the students (positive attitude about teaching profession etc.) and the overall the result of the schooling as its results (positive attitudinal change in students and good information gain by the learners). systematic evaluation helps in identifying strengths and gaps in the training program, enabling timely modifications and continuous improvement. Immediate feedback from stakeholders provides insights into the relevance, clarity, and effectiveness of the training content and delivery methods. Assessment of trainees' learning outcomes reveals the extent to which new knowledge, skills, and pedagogical strategies have been successfully acquired and can be transferred to classroom practice. At the behavioral level, evaluation focuses on observing changes in teachers' instructional approaches, classroom management, and their motivation toward adopting innovative teaching methods. Positive shifts in professional attitude, confidence, and engagement indicate the practical impact of the training. Finally, evaluation at the results level examines long-term outcomes such as improved student performance, enhanced learning experiences, and overall school development. By integrating evaluation across all four levels, training programs can ensure accountability, effectiveness, and alignment with educational goals, ultimately contributing to sustained improvement in teaching quality and learning outcomes.

1.10 Teachers and educational system

A teacher's goal and objective are to educate pupils through giving information. One of the most dynamic forces in a school is the teacher. A school without teachers would be analogous to a body devoid of soul, a skeleton devoid of flesh and blood, or a shadow devoid of reality. The educator serves as the benchmark for gauging the accomplishments and goals of a country. Millions of children's destiny and characters are shaped by their teachers, who serve as role models for their pupils. Since today's youth will become tomorrow's leaders, they are in that sense the real builders of the country. There is no denying the role that teachers play in the educational process. The National Policy on Education (1986), which acknowledged the value of teachers, correctly said that no educational system could be more than the caliber of its instructors.

1.11 Teaching skills and their Components

An illustration of the component abilities that make up the intricate process of teaching is shown in the table that follows (Toto et al 2021, Zhang et al 2021). In order to demonstrate that he is an effective educator, a competent teacher would demonstrate the necessary abilities listed in Table 1.1. Teaching skills are not isolated actions; rather, they are a combination of interrelated component abilities that collectively contribute to effective classroom instruction. These component skills include planning and organizing lessons, presenting content clearly, using appropriate teaching aids and technologies, questioning and probing student understanding, managing the classroom environment, and providing timely feedback and assessment. An effective teacher also demonstrates skills related to communication, motivation, and learner engagement, ensuring that students actively participate in the learning process. The ability to adapt teaching strategies based on learners' needs, prior knowledge, and learning pace is another critical component of teaching competence. Furthermore, reflective skills such as self-evaluation and continuous professional improvement enable teachers to refine their instructional practices over time. Thus, teaching skills can be viewed as a structured set of component abilities that, when integrated effectively, enhance learning outcomes and promote meaningful knowledge construction. Mastery of these components allows teachers to create supportive, interactive, and learner-centered environments, ultimately leading to improved academic achievement and positive attitudinal development among students.

Table1.1: Teacher skills and components

S.No	Skills	Components
1.	Writing instruction/objectives	Clearness, applicability to the aims and domains, and attainability in terms of the student's result are all important.
2.	Organizing the content	Logical arrangement based on the student's needs.
3.	Setting up a classroom to introduce the instruction	Establishing a relationship, offering assistance, obtaining attention, providing guidance, and making sure that resources like chalk, duster, and aids are available.
4.	Introducing the lesson	By making connections between the students' prior knowledge and the primary ideas, the instructor may ask the class about what they have learned in the past and the present subjects that the students might already be familiar with, or the instructor may set up scenarios in the classroom and then make references to the pertinent information.
5.	Forming Questions in the Classroom	Asking questions that are clear, specific, and appropriate for each level of the material while maintaining proper grammar.
6.	Delivery and dissemination of questions	Questions should be dispersed evenly, answered at the proper pace to allow for thought.
7.	Response management	Managing student answers by pushing,

		retraining, and getting more information, as well as accepting, asking critical awareness questions, refusing, and redirecting.
8.	Explaining	Clarity, flow, connection to the material, and hitting on the most important points.
9.	Explaining with examples	Easy to understand, fun, and related to what is being talked about.
10.	Utilizing teaching tools	Suitably sized, pertinent to the subject matter, suitable for the students' level, presented, and used.
11.	Changing the stimulus	Body language, motions, changes in pitch and accent, as well as stopping and changing the way you talk.
12.	Reinforcement	Utilization of complimenting phrases and words accept and use student ideas, repeat and rephrase student ideas, use of positive and encouraging body language and emotions, and writing student comments on the blackboard.
13.	The lesson's pace	Lesson speed should be changed based on the students' level and the content's level of challenge.
14.	Getting students to participate	Giving students the chance to participate more by asking questions and building an environment where participation is encouraged.
15.	Utilization of a blackboard	Enough, proper, and legal in terms of the material addressed.

16.	Finishing the lesson	Summarizing, making connections between what they are learning now and what they already know, and making connections between what they learned in class today and what they will learn in the future.
17.	Providing assignments	Adequate for the subject taught and student level.
18.	Assessing the student's growth	Use of suitable questions and notes that are related to the learning goals.
19.	Identifying students who are having trouble learning and taking steps to help them.	Find students who are having learning problems and find out what causes them. Then, use the right educational methods for their type and amount of learning problems.
20.	Class management	Reinforcing paying attention behavior and giving clear instructions on how to stop not paying attention behaviours, as well as dealing with a student's unruly behavior in the right way.

Effective teachers use positive reinforcement strategies such as praise, rewards, and encouragement to sustain attentive behavior, while consistently addressing inattentive or disruptive actions in a calm and constructive manner. By providing clear, concise instructions and maintaining consistent routines, teachers can minimize confusion and off-task behavior.

In addition, successful classroom management requires the ability to anticipate potential behavioral issues and apply appropriate preventive strategies. This includes engaging students through interactive teaching methods, maintaining appropriate teacher–student rapport, and ensuring equitable participation. Handling unruly behavior with fairness, empathy, and professionalism helps maintain a supportive atmosphere that fosters self-discipline, mutual respect, and effective learning for all students.

1.12 Concept of in-service teacher training

Effective teacher education is essential for a nation's progress, and effective teacher preparation produces effective teachers. Pre-service education and In-Service Education and Training (INSET) are the two separates but connected stages of further teacher education. In its widest definition, INSET refers to everything that a teacher encounters throughout their tenure, whether directly or indirectly assisting them in carrying out their professional responsibilities. A teacher may work for any length of time up to 40 years. Over this extended duration, his line of work has seen constant changes in demand due to shifts in goals, legislation, technology, society, and the wider globe. It is essential that educators engage in ongoing in-service education to stay current with changes in their field and to adapt their attitudes and abilities to fit their evolving duties (Asghar et al 2022).

Without a doubt, preservice education is the first step in a teacher's professional growth, which is then reinforced via in-service training programs. Different educationists have given different definitions to in-service training for teachers. However, INSET is generally understood to be the personal and professional growth of serving teachers through a wide range of events and activities that enhance their knowledge of educational principles and practices, as well as their academic and practical education. INSET stands for "in-service education and training," which is the portion of instruction and exercise that instructors get while they work. INSET, in general, refers to employee education and training intended to advance their competencies in a particular field or profession. It happens once someone starts having job-related duties. It might also be seen as including all of the experiences and activities that the teaching staff had while they were in service. Put another way, the goal of INSET is to influence employees' behavior toward their profession in ways that are desirable. Only when in-service teacher training programs are carefully designed with a clear goal can these desired improvements be ascertained.

Additionally, as the aforementioned definitions show, INSET is a hands-on activity that helps instructors advance their professional knowledge and abilities throughout the learning process. Thus, the goal of in-service training and education is maintaining the teachers' professional development, and it is designed and offered in a manner that fosters in them a positive outlook on raising their own game in order to improve student learning. In order to be prepared for the difficulties of the next century, educators must shape themselves to fit the

Demands of the classroom. Therefore, INSET helps instructors acquire the abilities needed to carry out their jobs with more assurance and efficiency. It aids individuals in becoming competent and skilled workers.

The idea that a teacher is the "backbone" of any educational institution is widely acknowledged. A pre-service education alone wills not enough to prepare a person for the workforce of the future. While INSET gives instructors opportunity to advance in their careers, it also assists them in starting jobs. Thus, it is the training and education they get while working as teachers. It is available to teachers at any point from the beginning of their employment until their retirement. In addition to assisting educators in assimilating societal changes, INSET encourages them to make contributions by developing cutting-edge curricula and creative teaching methods. Being a teacher requires constant learning throughout one's life; without it, certification would be all that remains. As such, an important phase of the teacher education continuum is in-service training. Pre-service education never fully satisfies the needs of the educational system or instructors, of course. As a result, the foundation of INSET is the idea that educators are lifelong learners and that in-service training and education are ongoing processes that teachers engage in throughout their careers.

1.12.1 Need for In-service teacher training

Effective and intentional in-service training is essential to the successful operation of any profession. Various forms of in-service training programs, such as seminars, workshops, talks, symposiums, orientation programs, and refresher courses, are arranged for this reason. Since in-service education and training, or INSET, is a lifelong learning process, it is expected to be the longest and comparatively more significant than pre-service education. Compared to other professions, the teaching profession is more in need of it because to the fast and advanced changes in topic areas, school curricula, educational technology, socio-political situations, and teacher work expectations. It was said correctly by National Policy on

Education (NPE) (1986) that "No nation can raise above the level of its teachers." As a result, educators have a lot of duty (Hofmeister et al 2020).

The job of a typical teacher nowadays, regardless of background, experience, or training, has likewise become increasingly difficult and demanding. As a result, INSET plays a crucial role in the initiatives to significantly enhance the educational system. In fact, since our nation

Gained its independence, there has been a constant demand for in-service education and training. According to University Grants Commission (UGC) (1949), "It is extraordinary that our school teachers learn whatever subject they teach before reaching the age of 24-25 and their further education is left to experience, which in most cases is another name for stagnation." As a result, evolving theories of education and methods of development have made even professionally qualified educators obsolete and less productive. Numerous laws, conferences, committees, and commissions both domestically and internationally have recognized and stressed the need of teacher training and in-service education. According to Diamond (1991), in-service teacher training programs provide practicing educators with a toolkit of information, skills, attitudes, and other behaviors that will help them become better educators (Vogt et al 2020). A particular focus on teacher preparation and in-service education has been seen in reports from several committees and commissions since independence. In June 1966, the Education Commission submitted a report that recommended the implementation of a comprehensive, organized, and synchronized continuing education initiative. This program should ensure that every teacher has the opportunity to participate in A minimum of two to three weeks of in-service education is required every five decades of employment. Teachers must close the growing knowledge gap that exists between the material they are expected to teach now and what they learned during their pre-service training. Not a single educator in the modern day would concur that pre-service training is enough for their lifetime professional competency. Therefore, continuous professional development is essential to keep teachers updated with emerging pedagogical practices, curriculum reforms, technological advancements, and changing learner needs. In-service education programs provide a structured platform for teachers to refresh their subject knowledge, enhance instructional skills, and adopt innovative teaching strategies that align with contemporary educational standards. Regular participation in such programs also promotes reflective practice, collaboration among educators, and professional growth over time. By engaging in periodic in-service training, teachers can effectively respond to evolving classroom challenges, integrate new methodologies into their teaching, and improve student learning outcomes. Hence, sustained in-service education should be recognized as a fundamental component of a teacher's professional life, ensuring long-term competency, adaptability, and excellence in teaching practice.

1.13 Current Status of STEM Education in Vietnam

In Vietnam, STEM instruction first started in 2015. Since then, Vietnam has seen a wide range of STEM activities, the most of which have been informal in nature. Initially, talented educational institutions, universities, and independent educational centers provided a wide range of STEM activities, such as scientific demonstrations, robotics competitions, science settlements, and STEM groups, and more, whereas public schools only slowly implemented STEM instruction. In addition, there are community events like STEM days in communities or schools and National STEM Day. Parents, colleges, and educational organizations were all participated in these activities in addition to students, instructors, and educators. Teachers and school administrators often embrace STEM education rapidly due to the extensively distributed community influence within the educational community. The rigidity of the present curriculum and a shortage of STEM resources and laboratories are only two of the several obstacles that Vietnam's formal STEM education must overcome. To enhance STEM instruction in schools, Vietnam's Ministry of instruction and Training implemented the 2nd High School Industry Improvement Program.

There isn't yet a formal STEM curriculum, however. To include STEM modules, educators must adjust the present curriculum and set up a workable schedule. Models, experiments, and simulations are used in STEM education because it is an innovative approach. Implementing STEM education is hindered by the dearth of STEM resources and STEM laboratories (Quy et al 2023).

1.13.1 STEM Education Development in Vietnam

STEM education, which stands for "Science, Technology, Engineering, and Math," was established by the “National Science Foundation (NSF)” in the US in the initial 2000s. This interdisciplinary method to education integrates difficult hypothetical impressions with actual life experiences. With the support of this strategy, students may improve their STEM literacy, use science, technology, engineering, and math in real-world settings that link the workplace, the community, and international business, and become more competitive in the new economy. Because of the differences in their political, social, and technical backgrounds, different nations have different STEM curricula (Pham et al 2023).

A campaign to include the arts into the curriculum is now underway. The Ministry of Learning and Training initiated many high school scientific study groups in 2006-2007 to prepare for participation in the "International science and engineering fair" (ISEF) on the municipal and provincial levels, which was the informal introduction of STEM in Vietnam. Since then, several local, regional, and national competitions have been held under this program in order to choose the top teams to represent their country abroad. Early in the decade, certain large-city private education institutions started bringing in STEM curricula from overseas to teach as other activities at some schools. In a similar vein, Western organizations and Vietnamese tech businesses funded a robotics competition that served as the impetus for integrating STEM into Vietnam's educational system. Since then, STEM education initiatives have expanded throughout Vietnam in a variety of models and forms and have drawn increased interest from both the country's management and non-governmental groups. Routes to schooling and STEM-related jobs in Vietnam are created either internally or through joint ventures between the Vietnamese government and many international countries. Multilateral organizations including the “World Bank, Asian Development Bank, United Nations, European Union, and multinational firms” are crucial in helping Vietnam’s business and technology sector, and believe. Through the distribution of scholarships, workplace Human Resources Development (HRD) practices, and support for vocational education, Australia's assistance program to Vietnam is dedicated to improving HRD through education and training.

In early 2016, the "Building University-Industry Learning and Development through Innovation and Technology (BUILD-IT)" partnership project was designed and implemented in Vietnam in cooperation with "Arizona State University and the United States Agency for International Development (USAID)". BUILD-IT, overseen through the "Higher Engineering Education Alliance (HEEAP)", is the latest initiative in a series of Southeast Asian projects led by USAID and the Ira A. Fulton Schools of Engineering at Arizona State University. The primary goal of the BUILD-IT partnership is to enable students to concoct for and subsequently track STEM jobs, hence facilitating cooperation between institutions and the corporate sector. In order to do this, the project hosts forums for the development of scholarly projects and offers networking and scholarship prospects for females in STEM.

In addition to supporting and training about 5500 Vietnamese participants—of whom 27% are women in engineering education, HEEAP has dedicated more than ($25 million) to creativity in higher education. Moreover, scholarships have been awarded to 436 female students at Vietnamese vocational institutions who are pursuing technical education, additionally, "Arizona State University" has hosted two Women in Engineering a graduate degree Fellow program participants. The British Council is now looking for candidates for its STEM Learning Initiative in Vietnam to promote collaboration and knowledge sharing regarding STEM education approaches between the United Kingdom (UK) and partner nations, especially with the objectives of enhancing human potential, restoring the economy, and enhancing societal well-being. The British Council works to promote educational excellence centers develop pedagogies that improve STEM topics, and disseminate information about the value and significance of STEM education.

1.14 What Science, Technology, Engineering, and Mathematics does?

1.14.1 Science

STEM science is divided into two groups. Natural sciences include biology, chemistry, and physics. Formal science includes statistics, logic, and mathematics. Its categorization scheme is distinct from those of the other branches of science. Sociology, political science, and psychology make up social science, which is the third main branch of science. Together with the arts and humanities, this discipline forms the counter-equivalent of HASS, or Humanities, Arts, and Social Sciences. Science workers' fields of study are the material world and the biosphere. Additionally, they employ techniques of testing and observation to piece together the facts. According to Julie Herrick, a volcanologist at the National Museum of Natural History at the Smithsonian Institution in Washington, "science becomes the lens through which the scientists understand the humanity."

The creation of new knowledge is the responsibility of STEM workers. Scientists who provide knowledge on the limitations on the use of harmful chemicals in agricultural areas also help with policymakers. Research, producing proposals, academic papers, and presenting findings are among a scientist's primary responsibilities. Science technical assistants aid scientists by gathering samples for experiments and other odd chores. Employees rely on scientific methods to impartially assess hypotheses and models. To generate dependable data patterns, scientific methods must be used in iterative studies. Experiments support the theory prediction and provide evidence for the hypothesis. Though new facts keep coming to light, conjectures with the strongest supporting evidence are recognized. Based on the area of space/universe examined, the scientific disciplines classified include earth science, life science, space science, physics, and chemistry (Devasia et al 2021).

1.14.2 Technology

The creation of commodities and services is the ultimate objective of all scientific study. Scientists create technology to accomplish the predetermined goals of a scientific inquiry. The term "technology" encompasses all of these abilities, methods, procedures, and frameworks. Systems or machines are constructed by combining many forms of technology. Additionally, this system converts user input into output for the purposes for which it is designed. These systems are referred to as technical systems or technological systems. The end user does not have to understand how the machine's internal mechanisms operate. Technology professionals employ engineering and science to build and debug computers and information systems.

For example, technology workers build and manage networks and databases and design software programs to address common issues like online transactions and shopping. Appreciations to technology, employees may interact with one another across an interface and carry out a variety of swift and economical operations, including exchanging videos and doing business. Technologists create and build hardware, software, and systems, then test, maintain, and enhance them in their job. These initiatives attempt to use technology to address certain problems. Cryptography, programming, artificial mobile computing intelligence, and operating systems are all included in the computer and information sciences' STEM technology field.

1.14.3 Engineering

The use of science, math, and technical expertise to solve practical issues such creating novel materials, goods, systems, or constructions is known as engineering. For example, engineers designing automobiles generate blueprints for fuel-efficient vehicles, engineers designing train stations build innovative designs to accommodate additional travellers, and engineers creating environmental remediation equipment construct environmental cleanup technologies.

Engineers enhance and increase public accessibility to objects. Industry classifications such as automotive, petroleum, textile, and aerospace are used in technology domains.

1.14.4 Mathematics

Mathematicians understand and explain problems in real life by using numbers, logical connections, and spatial notions. An operation research analyst assists in determining the most effective approach, whereas a mathematician utilizes established procedures to address scientific issues in the physical sciences and engineering. The foundation of all sciences, engineering, and technology is mathematics. Their job is to recreate real-world models, look for patterns in data or logic to draw conclusions from, evaluate mathematical relationships. Numerous topics are included in mathematics, including geometry, algebra, calculus, statistics, and game theory.

1.15 The Domain of Attitude, Knowledge, and Application of STEM

Strongly positive to strongly negative, as well as any point in between, are the extremes of attitude. Attitude may be defined as the comprehensive evaluation of an object across multiple levels, including both positive/negative and pleasant/unpleasant aspects. According to a different definition, attitude may be favourable, unfavourable, or neutral toward a thing or an action. According to this study, "attitude" refers to a science teacher's thoughts and sentiments toward STEM, as well as whether or not they are curious in STEM and how it is being implemented in the classroom. Research on teachers' attitudes in the context of integrated STEM education is comparatively lacking, particularly when it comes to personal variables and points of view (Wahono et al 2019).

For this reason, the present study's assessment of teachers' attitudes toward STEM education is important. Knowledge is the next element to be discussed. The concept of knowledge is wide-ranging. It is not unexpected that using a quantitative survey to investigate this facet of teaching practice is made more challenging by the definition. Three categories of knowledge propositional, case, and strategic are used to categorize teacher knowledge in this research. To begin with, a propositional statement has a proper or wrong definition. People often look for information that has been gathered through teaching experience, or the wisdom of practice, expressed as statements. Information often involves analyzing the study on

Education and understanding its actual consequences. Case knowledge is specialized information that is well recorded and provides a detailed account of occurrences. Lastly, strategic knowledge is useful when a teacher has to deal with specific issues or difficulties that cross theoretical, practical, or moral boundaries and cannot be solved easily. Although experience is a valuable source of information, it is not the only method to learn. It is also possible to acquire knowledge through reasoned contemplation.

A number of earlier investigations tried to gauge knowledge. Research has been done on STEM awareness, particularly with regard to high school pupils. Through workshops and questionnaires, the researchers have collected data on parents' and students' knowledge and opinions about STEM education. However, there is still a dearth of information about STEM teacher expertise. Therefore, we defined the term "teachers' STEM knowledge" whatever expertise an educator in science may have on STEM instruction, such as the acronym's meaning, the goal of STEM learning, how to implement STEM in the classroom, and the connections between different disciplines. Evaluations of this kind of knowledge are essential to the advancement of STEM instruction.

1.16 Competence of STEM

The capacity to carry out an assignment in a professional manner is a combination of knowledge, abilities, and attitudes comprising competence. A student must possess conceptual knowledge, practical abilities, and attitudes in order to participate in activities relating to “science, technology, engineering, and mathematics (STEM)”. The number of interventions that are targeted at enhancing students' STEM competency is growing as the need for and interest in a workforce that is proficient in STEM fields continues to rise. STEM competence extends beyond the acquisition of factual knowledge to include higher-order thinking skills such as critical thinking, problem solving, creativity, and innovation. Students are expected to apply interdisciplinary knowledge to real-world problems, use technological tools effectively, and engage in engineering design and mathematical reasoning processes. Positive attitudes such as curiosity, perseverance, collaboration, and openness to learning are equally essential for sustained engagement in STEM activities. To develop these competencies, educational systems are increasingly adopting learner-centered and experiential approaches such as project-based learning, inquiry-based instruction, and field-based learning. These interventions encourage active participation, hands-on experimentation, and real-life application of STEM concepts. As a result, students become more confident, adaptable, and prepared to meet the demands of future STEM careers, thereby contributing to innovation, economic development, and societal progress.

Furthermore, the effective development of STEM competence requires supportive learning environments, qualified teachers, and access to appropriate resources and infrastructure. Well-designed STEM curricula should integrate theory with practice, encourage interdisciplinary connections, and emphasize real-world relevance. Assessment strategies must also move beyond rote memorization to evaluate students' problem-solving abilities, creativity, collaboration, and application of knowledge in authentic contexts.

In addition, partnerships between schools, industries, research institutions, and communities play a crucial role in strengthening STEM competence. Such collaborations expose students to real-world challenges, career pathways, and emerging technologies, thereby increasing motivation and career awareness. By systematically implementing targeted interventions and continuous support mechanisms, education systems can nurture well-rounded STEM competence, ensuring that learners are equipped with the knowledge, skills, and attitudes necessary to succeed in an increasingly technology-driven and innovation-oriented world. Moreover, the integration of digital technologies and emerging tools such as artificial intelligence, data analytics, robotics, and simulation platforms further enhances STEM competence by providing authentic and interactive learning experiences. These tools enable students to visualize complex concepts, experiment in safe virtual environments, and develop computational thinking skills that are essential in modern STEM fields. Equity and inclusiveness are also critical considerations in the development of STEM competence. Targeted support programs, mentorship initiatives, and gender-sensitive and socioeconomically inclusive strategies help ensure that all learners have equal opportunities to engage in and benefit from STEM education. By fostering interest, confidence, and sustained participation among diverse student populations, STEM education can build a robust and future-ready workforce. Ultimately, strengthening STEM competence among students contributes not only to individual career success but also to national innovation capacity and global competitiveness.

1.17 Cultivation of 21^{st} Century Skills

Global abilities that are critical to handling the difficulties brought on by the quick changes in the job markets both now and in the future are fostered by STEM education. Therefore, experts in STEM education have maintained that the main goal of STEM education should be to help students develop 21st century abilities, which include, but are not limited to, flexibility, critical thinking, problem solving, communication, teamwork, and self-management. The Council of Canadian Academies (2015) agreed that imparting fundamental STEM skills to students is crucial. There is a core shared by these capabilities and multidisciplinary abilities. The phrase "interdisciplinary abilities" describes the ability to collaborate with people in other areas and to understand the significance, purpose, and responsibilities that experts in other fields perform. According to research on the concept of interdisciplinary abilities, interdisciplinary teams frequently run into issues with communication caused via diversely minded colleagues, the proportion of experts to team captains, and the ability to come to an agreement, examine, and assess data as a group. The Association of Canadian Academics (2015) identified four essential qualifications: leadership competence, imagination, flexibility, and capacity for entrepreneurship, STEM professionals also need to master more general abilities like problem-solving, critical thinking, and productive teamwork (Lin et al 2023).

Numerous American firms, including Apple, Cisco, and Intel, came together to form the “Partnership for 21st Century Learning”. Several skill sets have been suggested by the group as being necessary for success in the twenty-first century: The skills encompassed in learning and innovation includes reasoning, creativity, troubleshooting, interpersonal interaction, and collaboration. The skills concerning information, media, and technology encompass media literacy, information, communication, and technological advances. Lastly, the life and career skills encompass self-direction, flexibility, responsibility and self-management, worker efficiency and reliability, social and international abilities, authority, and responsibility. The vital skills stated by the Collaboration for Modern Learning aim to represent the understanding of STEM as seen by STEM-focused organizations and scholars. However, they are not intended to be identical to the crucial skills needed in STEM or to imply that STEM abilities must encompass these capabilities.

The Council of Canadian Academies (2015) states that although defining the essential abilities that future STEM talent should possess is still challenging, the competencies that have been identified will help them address problems in the workplace going forward. STEM education should focus on cultivating students' abilities in continuous learning, management, innovation, flexibility, entrepreneurial activity, solving problems, thinking critically, and collaborative issue solving. This comprehensive skill set will equip them for the demands of the modern world.

1.18 STEM Teacher Education

Researchers are attempting to learn more about how to better equip teachers to use integrated STEM education in the classroom since it seems to have a good effect on students' learning and enthusiasm in STEM. The studies on STEM teacher preparation will be examined in more detail in this part (Weinberg et al 2021).

1.18.1 Teacher education in general

- The meticulous monitoring by programs of the performance of student teaching experiences,
- The degree to which the student teaching environment and the applicants' subsequent teaching assignments align with regard to grade levels, topic content, and student types,
- The quantity of reading and math homework, as well as the instructional strategies used,
- The emphasis in training programs on teaching candidates how to use certain techniques and instruments that they would subsequently apply in their clinical encounters,
- The options available to applicants to study the curriculum of the local district,
- A final project, which is usually a portfolio of work completed by students in classes, and

- The proportion of tenure-line academics employed by programs, which the researchers considered to be a viable indicator for financial commitment and program stability.

The following are some additional examples that may have an advantageous effect on preservice programs: relationships between theories addressed in courses and field experience practices; coherence and explicit modeling of educational pedagogy influenced by research between content instructors and schooling instructors; teaching tools for assessments; and working with diverse student populations were previously mentioned. It follows that these suggestions should be applicable to all teacher education, including STEM teacher education.

1.18.2 STEM instructor for Professional Development approaches

The main focus of professional development for STEM has been on improving instructor's experience of the subject matter, teaching abilities, and teaching methods are the instruments that provide organized growth that impacts teacher's practices and gains in student learning. One-on-one assistance, ongoing faculty group meetings, and short or multi-day seminars are examples of professional development session types (Wheeler, 2021).

Using hands-on instruction and then incorporating teaching strategies into the educational program during the course of personal growth has been defined as the concept of instruction teaching in STEM education. These procedures are evaluated utilizing pre/post, subjective or other types of linear, predictable evaluation methodologies. The results of these tactics are often perceived as an aggregate of the group, which is evidence of their reductionist nature (Cleary et al 2022). Developing high-quality programs that result in changes in behaviors that are sustainable over the long term is still a challenge for many organizations. According to research conducted by Osman and Cleary in 2020, the targeted outcomes of "professional development" (PD), such as the enhancement of teaching techniques and a positive impact on pupil comprehension, and are more important than the specific kind of PD.

According to Kaplan and Garner's research from 2020, the results of PD are often unexpected and vary from one comparable PD program to another with the same participants.

1.18.3 Teacher-Centred Learning (TCL)

The educational style known as teacher-centered learning is considered to be generally accepted. E-learning has been deeply ingrained as the primary method of education and is often considered the most favoured approach to instruction. TCL is characterized by the fact that it conceptualizes information as being transmitted from the instructor to the student, which places an emphasis on the student's function as a passive participant in the instruction process. The instructional methods consist of a didactic, lecture-based approach, with the teacher serving as the focal point of the learning experience. The content of the course often concentrates on a particular subject area, with a low emphasis on student reliability and a greater emphasis on the curriculum that has been set.

Assessment of learning is mostly accomplished via the use of tests, midterms, and multiple-choice examinations, which may lead to an environment that is seen as being competitive and individualistic. The transmission of information from the teacher to the student is the vehicle via which learning takes place, with an emphasis placed on memory and regurgitation as consequences of learning. It has been shown that this mode of education contributes to the perpetuation of achievement inequalities it negatively impacts pupils and hinders the learning process in STEM-related programs. Other factors that might be considered barriers education may include limited availability of information for pupil’s instructors evaluating students' level of comprehension, and the relative nature of the material covered in the course (Lau et al., 2024). Education that is cantered on the student is intended to overcome such obstacles through an important shift of the instructor's position, the student's function, and the material, the course delivery is significantly changed. Evidence has shown that it enhances student academic achievement by surpassing the acquisition of factual information and promoting critical thinking.

1.18.4 Student-Centred Learning (SCL)

The goal of professional development for STEM teachers is to improve student achievements by substituting a more reform-oriented method of instruction for traditional lecture-style instruction. Teaching and learning that has emerged as the cornerstone of professional development for their profession. Evidence-based education, which is characterized by active learning practices, is encouraged with the goal of reducing the achievement disparities that are observed among student communities. Research has demonstrated that it leads to improved academic achievements among student groups who are not adequately represented. Various forms of interactive instruction exist, including inquiry-based learning, which has shown the ability to enhance students' advanced cognitive abilities, ability to solve problems, and enthusiasm for science (Rappleye et al., 2024).

Despite the rising body of research that supports the use of such strategies, there is still reluctance among teachers to put them into practice. There is a limited understanding of the elements that influence the implementation and acceptance of SCL, in addition to a resistance to embrace it. The prevalent methods to professional development (PD), the sorts of research that are carried out, and the activity-based emphasis of STEM professional development all contribute to the difficulty of identifying and comprehending the cause of resistance.

Students are to be engaged in their education, which is the aim of SCL. The learning objectives for SCL demonstrate more advanced knowledge, solving problems, critical thinking, and active attitudes towards science. Studies have shown that SCL enhances learning results for student’s demographics that are underrepresented in STEM fields, supporting its contribution to the reduction of performance disparities in these fields. Despite the fact that student-centered learning (SCL) enhances essential parts of learning, it also modifies basic features of conventional education, it has caused SCL to be gradually included into STEM subjects. However, the majority of children will not get this sort of instruction because of this.

1.19 Education system in Vietnam

The latest modification to the Constitution on Education in Vietnam focuses on two primary aims to strengthen the nation's system of instruction in the realm of higher learning. These objectives are as follows: (a) to produce a workforce with a high level of education; (b) to educate well-rounded individuals who have an entrepreneurial mindset and are willing to serve the public; they are also well-educated, have good health, an aesthetic sense, and a sense of professional responsibility; Individuals possess the ability to stay updated with the most recent progressions in science and technology. They have the capacity to acquire knowledge independently. They are capable of generating and adjusting to the demands of the professional environment. Furthermore, they exhibit an entrepreneurial attitude (Le Ha et al., 2020). The 2012 Law on Higher Education provides more details on the sector's organizational structure and required measures of national responsibility. The "Ministry of Education and Training (MOET)" is in charge of the sector's overall regulatory framework. Apart from both of the national universities, there are other establishments that are managed by other ministries or municipal authorities. "Vietnam National University in Hanoi and Vietnam National University in Ho Chi Minh City" are the two national institutions that directly report to the Vietnamese government's Cabinet. The Ministry of Science and Technology is in charge of distributing research money to the higher education sector (MOST).

University and college education make up the postsecondary education industry, including instruction and certification for occupations. Added to this list are highly specialized research institutions without university affiliation that give PhDs. Over the course of the 2019–2020 academic year, was 76 research institutes, 237 universities, and 236 colleges. Since 2000, both the number of higher education institutions and enrolment has increased significantly. For instance, the number of schools and universities climbed from 178 to 442 between 2000 and 2015, while the enrolment of students surged from 899,500 to nearly 2.2 million. The rapid growth of the middle class and Vietnam's economy were the two main drivers of this expansion, as was the country's unusually high rate of transition especially in the early 2000s, through specialized high schools towards institutions as well as universities to colleges. There were 1,672,881 enrolled students at universities in 2019–2020. Six percent belonged to a minority group, and 54.6% of them were female. Vietnam has achieved remarkable progress in achieving gender-based parity in access to higher education, thereby fulfilling one of the major Sustainable Development (Tran et al 2022).

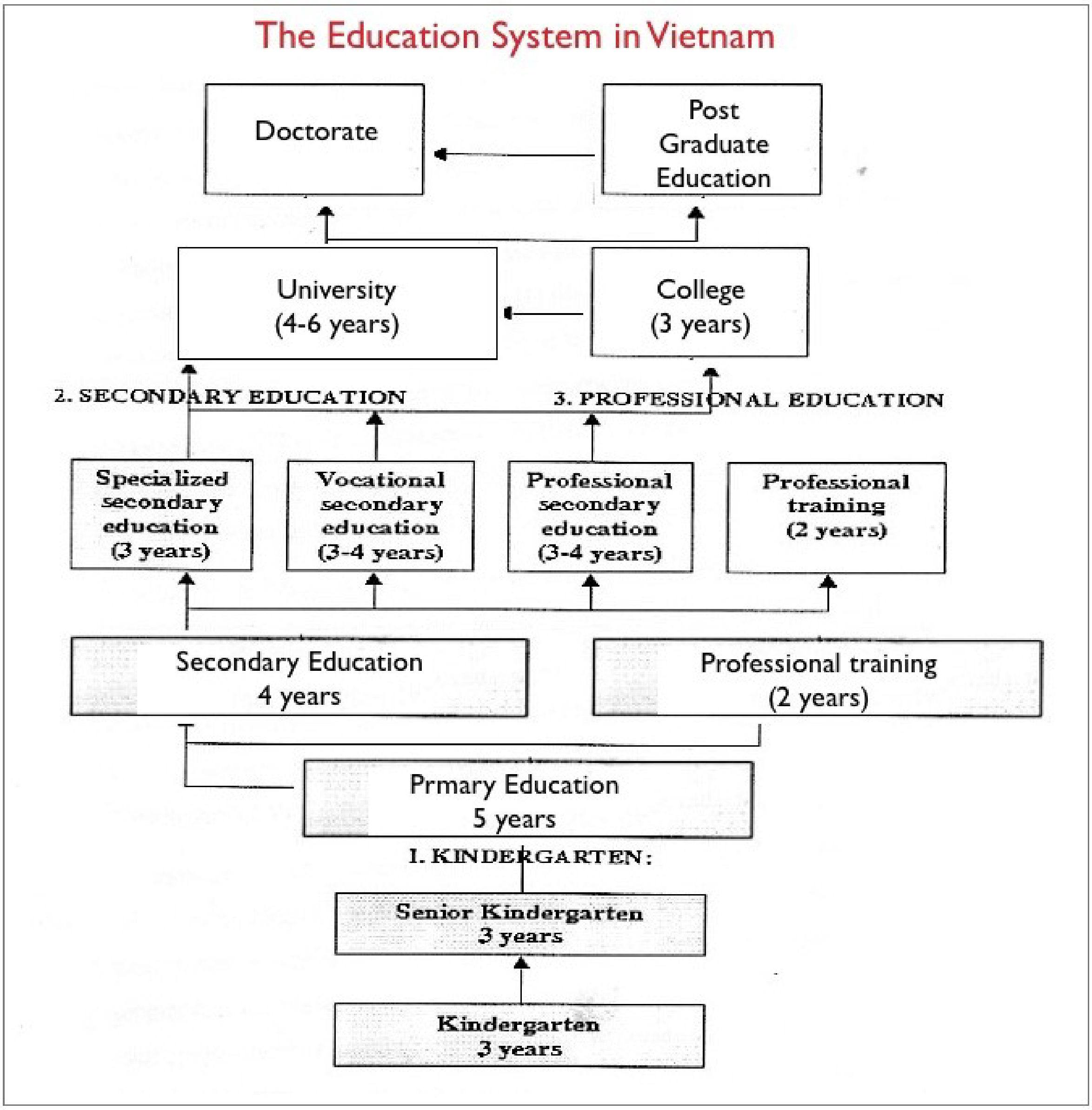

Fig. 1.6 Education systems in Vietnam

In Fig. 1.6 shows the overview of education system in Vietnam. The National High School Examination had 887,173 registrations in 2019, according to MOET data. Roughly 653,000 (74%) of these students enrolled in order to get admitted to a university or college, while roughly 223,800 (26%) only wanted to acquire the appropriate school completion certificate. Nevertheless, the quantity of open positions at public institutions and colleges was capped by MOET at 489,637 in 2019. This means that only 75% of applicants might be accepted into these institutions. Vietnam's higher education participation rate for those aged 18 to 29 is around 28.3%, which is lower than that of Malaysia (approximately 43%) and Thailand (almost 48%). To make public higher education more accessible to young people, MOET is gradually raising the enrolment ceiling. Right now, nevertheless, getting into a public university or college's degree program is still quite tough. 73,312 (87.7%) of the 83,587 Personnel employed at institutions of higher education from 2019–2020 were academic staff members. Between 2006 and 2018, the percentage of female academics grew from 42.5% to 48.5%. By 2025, 35% of academic staff members are expected to get a PhD, with 7% of them obtaining their degree overseas. This is the stated aim. In 2015, the ratio of students to lecturers was reported as 22.66. After then, this ratio has not changed.

The State nevertheless retains significant authority over the administration and governance of higher education, even in light of recent changes implemented by the 2018 amendment to the Law on Higher Education. The Higher Education Law, which was released in 2012, was a critical turning point for the industry's governance. It meant that public universities would have much greater institutional autonomy on a conditional basis provided their institutional governance structures and quality accreditation performance showed that they were prepared to use such authority. After then, progress has been sluggish. Right now, 23 public universities out of 171 have achieved autonomy.

These actions have brought about modifications to research management, university rankings, internationalization strategies, curricular frameworks and innovation, institutional autonomy and responsibility, and quality assurance. Central to these changes has been giving public universities more independence and incentives to improve their quality and efficiency. However, there is sometimes a big lag in Vietnam between the approval of policies and their actual execution, which makes change take longer to occur. Furthermore, even while institutional government and the way of life of teaching and learning have both seen substantial improvements; yet, many efforts at change remain scattered and of an ad hoc nature which has resulted in the changes' generally limited impacts.

1.19.1 Education Expansion in Vietnam

Increasing numbers of students have been a feature of higher education in emerging nations. There are various comparable explanations for the fact that in several Southeast Asian countries, including Vietnam, Indonesia, and Thailand, the number of people gaining access leading to greater education is exceeding population increase. The first is a direct effect of increased secondary school access, which raises the demand from each nation's citizens for access to higher education. The second is that talented people are becoming more valued as a result of shifting job options brought about by globalization. Not to mention, the governments of these nations understand the significance of higher education for their nations' future. Higher education is necessary for sustainable advancement even while it cannot provide quick economic prosperity (Truong et al 2021).

The "Doi Moi" system was introduced in Vietnam in 1986, marking the country's transition from an economically planned to an informal economy based on principles of socialism. Nearly every element of the Vietnamese socioeconomic structure was impacted by "Doi Moi." Following the implementation of this program, Vietnam saw significant social and economic transformations. The "Doi Moi" changes have had an instant impact and fundamentally altered the nation. Growth increased by 8 to 9 percent every year in the 1990s and continued to average 7 percent from 2002 to 2008. The need for skilled labor has increased as a result of this advancement, particularly for people with higher education.

The economic developments facilitated the growth of the system of higher learning, as well as the whole system of education. As a result, the availability of university degrees in Vietnam has significantly increased during the last two decades. There were only over 719 thousand students enrolled in 69 institutions in 1999. But by 2015, there were 223 institutions with about 1.75 million students, a dramatic rise. With a tertiary gross enrollment rate of 22.3 percent in 2010, Vietnam seems to have moved into the second phase of its higher education growth.

Vietnam's economic reforms made it possible for sectors to grow and for international investors to get involved. Due to the economy's opening to international trade, international investors are highly motivated to penetrate the Vietnamese market. Consequently, there has been a rise in demands for skilled labor; necessitating efforts to meet the growing need higher education must create more graduates. In an environment like this, human capital becomes crucial to the nation's development, and its leaders saw that restructuring and enlarging the educational system was necessary to attain the desired level of economic growth. For instance, the Vietnam Communist Party's Ninth Congress acknowledged the significance of science, technology, and education for the industrialization and modernization of the nation by 2020.

There have been three major changes to the government policy framework that have directly aided in the growth of higher education in Vietnam: the promotion of private postsecondary educational institutions;2) the relaxation of enrolment quota restrictions; and3) the growth of the network of postsecondary educational institutions. Regarding the first, it's crucial to remember that before to 1989, there were no private colleges in the nation. Following the founding of the first pilot private university, the Thing Long People-founded Learning Center, the government began encouraging the creation of private universities. From this vantage point, the government passed Resolution 04-NQ/HNTW in 1993 and Decision No. 240/TTG, which discussed the idea of a private university, the same year. Because the nation is communist, the notion of "privatization" was delicate, and discussions gave rise to the more widely accepted conception of "socialization of education."

The administration relaxed enrolment quotas in 1993 with the adoption of Resolution 04-NQ/HNTW, the second significant change. From this angle, the tight supervision over enrolment quotas was progressively relaxed, and institutions were allowed more freedom to choose their own quotas. The Higher Education Reform Agenda (HERA), also known as the 2006–2020 Resolution on the Renovation in Higher Education Management, has granted higher education institutions the authority to determine how many students to enrol depending on staffing levels and other resources. Since 2007, the government has been building new universities around the nation in an effort to increase enrolment in higher education.

1.19.2 Teaching and teacher education Vietnam

Families, communities, and society at large place a high value on education in general and children's education in particular in Vietnam. Referred to as "teacher education or college

And university programs, teacher education are firmly rooted throughout the nation. Therefore, pre-service teachers in Vietnam get their education at teacher training institutions or universities in accordance with the national curriculum for teacher education. Because of this, pre-service teachers are seen to be completely prepared to start working as teachers in K–12 classrooms after completing their teacher education degree. The word K-12, as used in this document, refers to the primary and secondary education system in Vietnam, which covers grades 1 through 12.

This is similar to comparable education systems in Western nations. However, issues with instructors, education, and teaching in Vietnam have come up recently. University teacher education programs are part of higher education, and they are mostly based on the Soviet Union model. Due to the imposition of a limited, career-specific framework on teacher education, this approach is no longer deemed suitable. Some have questioned the topic understanding, language proficiency, and pedagogical skills of teacher applicants.

1.20 Teachers beliefs about STEM integration

The instructors believed that their personal drive and desire for creative teaching approaches determined how involved they would be in STEM education. According to the instructors, STEM is a new educational trend that calls for proficiency in both new subject matter and instructional strategies. While some educators were somewhat reluctant, another claimed that they were actively involved in the creation, organization, and teaching of STEM courses. The fact that STEM was an elective rather than a required subject in the general curriculum was one of the barriers affecting instructors' motivation. This indicates that the criterion for evaluating teachers did not incorporate STEM education. For example, a said that STEM integration was up to the teachers' initiative, inventiveness, and flexibility and that it was optional. STEM was not taken into consideration or addressed in academic or professional settings. In order to plan STEM classes, teachers have to do all of the organizing themselves (Nguyen et al 2020).

1.21 Challenges faced by Vietnamese high school teachers in STEM integration

The present research looked at the difficulties Vietnamese high school teachers had integrating STEM. Consistent with other research conducted in different school settings, the educators encountered a range of challenges while creating, organizing, and instructing STEM programs. The following factors contributed to these challenges:

- Inadequate teacher preparation for STEM teaching,
- Absence of instructional resources, assessment protocols, and a curricular framework,
- The lack of enough time, space, and technological resources
- The educators' views on STEM education and their learning objectives
- Limited STEM-specific training and interdisciplinary competence among teachers.
- Absence of well-defined curriculum, instructional materials, and assessment strategies.
- Insufficient time, physical space, and access to technological resources.
- Limited awareness, confidence, and positive perception of STEM education among educators.
- Overemphasis on theoretical content with minimal hands-on and experiential learning.
- Inadequate use of innovative pedagogies such as project-based and inquiry-based learning.
- Challenges in evaluating interdisciplinary learning outcomes effectively.
- Inequitable access to STEM opportunities among diverse learner groups.

1.22 STEM Education Center Functions

STEM Education center function as hubs to improve Science, Technology, Engineering, and Math learning by unifying efforts, providing faculty training in evidence-based practices (EBIPs), researching effective teaching, offering student programs (like workshops, labs, games), fostering community engagement, and developing resources to boost critical thinking, problem-solving, and innovation for a tech-driven world.

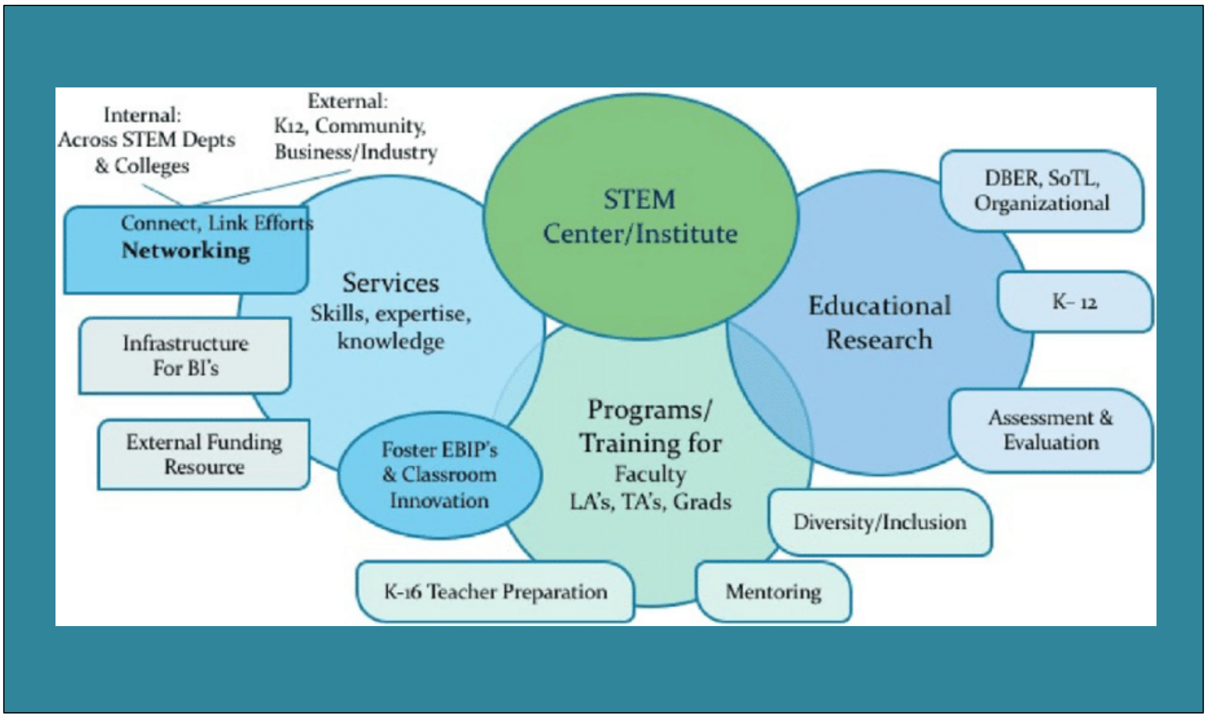

Fig. 1.7 STEM Education center functions

Core Functions

- **Faculty Development:** Offer training, resources, and support for instructors to implement innovative and effective teaching methods (EBIPs).
- **Educational Research & Scholarship:** Conduct studies and contribute to the knowledge base of STEM education, often through Inquiry-Based Science Education(IBSE).

- **Program & Curriculum Development:** Create hands-on activities, virtual labs, educational games, and workshops to make learning engaging.
- **Networking & Collaboration:** Serve as a central point to connect departments, faculty, students, and external partners (industry, K-12 schools).
- **Assessment & Evaluation:** Measure learning outcomes and evaluate the effectiveness of new programs and teaching strategies.

1.23 STEM Advantages

A STEM environment is one that encourages students to work together in order to tackle significant difficulties and to learn utilizing the process of exploration, discovery, and innovation by making use of real-world problems and circumstances.

- Encouraged in the development of creative thoughts,
- Curiosity being the driving force,
- Encourages the use of a variety of thought processes,
- encouraged the development of a feeling of belonging and collaboration,
- Discover how to learn from and alongside other people,
- Acquire new abilities, become proficient in technical capabilities, and
- Acquire the ability to solve problems effectively, to be creative, to be self-aware, and to think rationally.

Students have the opportunity to develop skills that are essential for in the modern era, skills such as flexibility and solving issues are highly valued complex communication, and system thinking, for the purpose of facilitating the resolution of grand challenges that have not yet been resolved at the local, national, or global community (Carlisle et al 2018). STEM education helps to bridge the gap between racial and gender differences, which are sometimes encountered in the fields of mathematics and science. Students who successfully complete a STEM program have the following advantages in addition to the broader benefits of STEM:

- Education that is equitable for everybody,
- Investigate topics in deeper detail, study
- The development of abilities in critical thinking
- Better equipped for the rigorous coursework that is required in a college or university.

In addition, it is important to point out that students favour STEM compared to other areas of study for the following reasons:

- They have done well in these areas, are intellectually challenged, and have a strong interest for the topic of study.
- They have the opportunity to get a decent wage and are provided an excellent work potential. The salaries and possibilities for promotion in STEM jobs are often greater than those offered in non-STEM industries. STEM careers also provide more opportunity for development.
- In these industries, there is a need for trained personnel, and the STEM idea has garnered backing from a variety of organisations, including the government, schools, businesses, and the community.
- It is important to them to make a difference.

1.23.1 Pedagogical Challenges in Higher Education STEM courses

All categories of "Institutions of Higher Education" (IHE), including community, investigate, community colleges ration underrepresented populations, for-profit, distance learning, and online learning, offer STEM majors. Of all degrees in science and education, 71.5% are offered by public universities. Bachelor's degrees in science and engineering have been steady at 35–38% of all degrees given between 2000 and 2019, despite an increasing need for these degrees in the labor market (23% of the overall workforce in 2019) (NCES, NSF, 2023). In order to satisfy demand, the National Research Council (2012) proposed that IHEs graduate one million STEM degrees yearly between 2012 and 2022. STEM degrees expanded from 561,000 to 1,087,000 between 2000 and 2019. But even with this rise, there is still a difference in graduation rates between students from underrepresented groups (Burke et al., 2022).

The laborious expansion of STEM in higher education, particularly among students from marginalized backgrounds, is explained by a number of factors, according to research. The lowest retention rates for first- and second-year students and the high Drop, Fail, Withdraw

(DFW) rates are the most noteworthy. Students from minority and low-income backgrounds are especially impacted. According to (Schneider et al 2021), just 21.6% of bachelor's degree holders in science and engineering are minorities. A number of factors contribute to STEM majors quitting, such as the discriminatory environment in the classroom, didactic instruction, lack of mentorship, and general campus discrimination a problem that often starts in K–12. In reaction to this low retention, which mostly affects students from underrepresented minority groups, as well as consumer demand?

The majority of STEM professional development programs concentrate on student-cantered learning (SCL) approaches. When compared to conventional lecture-based course material delivery, SCL approaches are evidence-based strategies that have been shown to provide overall improvements in student results. However, even with the strong evidence that supports the effectiveness of SCL, lectures are still the most common way that instruction is delivered; according to extensive research, just 18% of classroom observations are classed as SCL. Furthermore, studies on the effectiveness of these PD programs continue to provide results with substantial impact variability and limited reproducibility.

It has been determined that a number of factors, such as faculty beliefs, prolonged Factors contributing to the prevalence of focused on teachers methods include exposure to such methods, faculty choice, lack of awareness of SCL, limited time availability, large class sizes, institutional pressure, and departmental choice have an influence on teachers' incorporation of SCL activities. Higher education institutions nonetheless carry out professional development initiatives and provide incentive-based professional development in an attempt to persuade faculty members to embrace SCL pedagogies, but they do little to solve systemic problems.

The understanding of the fundamental shift in teachers' belief systems required to support the long-term acceptance of a new teaching paradigm is absent from both the existing methods to designing professional development programs and the research on their efficacy. A change in pedagogy from one where the instructor has exclusive control over power, attention, initiative, and information sources in the classroom to one where they are shared with the students is necessary to conversion from TCL-SCL. To effectively adapt to

This transformation, teachers' presumptions, convictions, objectives, and pedagogical approaches must also change. Teachers deeply held motivational and perceived action possibilities are not taken into consideration when PD that teaches SCL techniques is the only activity they take part in. The STEM educator must also deal with people who could oppose these new pedagogies, such as students and other instructors, business systems and mind-sets that may not be receptive to these novel approaches, as a result of the pedagogical shift.

It is necessary to take into consideration the intricate, unique, and contextualized character of each instructor's learning, motivation, and behavioral shift while designing for such change. It has been suggested recently that research on professional development for STEM instructors ought to be thoughtfully conceived from an intricate paradigm that might provide fresh theoretical understandings to better direct the planning of professional development and evaluate the transformative processes of teachers. This study aims to enhance educators and researchers' comprehension of the attributes of professional development, enabling them to more efficiently promote the desired transformation in the teaching methods of STEM teachers (Trapper et al., 2024).

1.23.2 Disadvantages in STEM education system

According to Tucker, the whole educational system is flawed, which means that innovative initiatives including STEM education won't provide the expected outcomes. For instance, it is unimaginable to construct a robust STEM secondary curriculum on top of a poor primary one. This is particularly true in the United States (and other countries), where elementary school instructors may teach arithmetic without ever taking a math course at the college level. It is necessary for educators to make investments in their professional development in order to improve their level of self-assurance and level of effectiveness when it comes to teaching STEM subjects. The fact that educators are required to build their own STEM educational model is yet another disadvantage of the STEM model. This is due to the fact that the model does not give clear instructions for educators to follow. Additionally, it should be noted that there are not presently no national standards for STEM education, nor are there any accreditation requirements for instructors working in these programs.

- In order for students to become and continue to be involved in STEM fields, there is a requirement for high-quality instruction.
- The challenging nature of topics in the STEM fields.
- The passage from elementary school to secondary school after primary school.
- Students of a certain gender. It should come as no surprise that men and girls have vastly diverse interests and concentrate on distinct aspects of life.
- Attitudes regarding future prospects and occupations.
- The poor perceptions of achievement and the bad preconceptions around STEM fields.
- It is important to consider the impact that influences, such as teachers, the media, and educators, play.
- The kids' lack of motivation and preparedness is unfortunate.
- It is difficult to connect with individual students. A few ways to make connections include: STEM competitions, summer camps and programs, Fablabs, etc.
- Limited cooperation among educators in the area of research across STEM disciplines.
- A poor way of assessing, preparing, and delivering the material.
- Students have minimal experience, particularly in practical training.
- The educational system is unable to provide help because of the limited funding available.
- The teaching materials and the laboratory facilities are in a poor condition.

The development of a comprehensive STEM program necessitates the acquisition of expensive textbooks, lab spaces, equipment, materials, and curriculum. Consequently, it is of the utmost importance to discover methods to reduce the aforementioned expenses in the event that there is insufficient financing for STEM education. The inadequate and outmoded equipment that schools supply is another part of the limited financial resources that are available for STEM instruction. Technology is a tool that should be included into a school, and its usage should not be restricted to the use of computers and the internet. Despite the fact that technology has the potential to assist and improve scientific education, it is not sufficient for successful learning to take place. However, when combined with proper scaffolding from teachers and other professionals, technology could assist inquiry-based learning.

1.24 Problem statement and research gap

The existing state of STEM education hindered by improper quality control, impact the prediction accuracy, feature selection failure so on. The existing issue fails to provide the comprehensive solutions among those challenges. The primary issues are

- **Training and evaluation:** In the previous research lacks the sufficient evaluation of the training the teachers for online integrative STEM education that leads the potential time constraints and reduce the effectiveness.in further the pre-service teachers to self-reports doesn't accurately reflect their knowledge, impact the quality of STEM education.
- **Model performance and prediction:** In the existing work the feature selection does not significantly improve the model performance that leads to decrease the prediction accuracy in STEM education.
- **Integrative STEM education challenges:** in the previous work they had a challenges in student engagement , changes form physical to online mode and improve the content quality are the important hurdles in the implementing the effective integrative STEM education and the student during classes had a disinterest and related issues to faculty adaptation.

These limitations collectively reduce the effectiveness of integrative STEM instruction and hinder the achievement of intended learning outcomes. Inadequate interaction, reduced hands-on activities in online environments, and insufficient alignment between pedagogy and technology often lead to passive learning experiences. Additionally, the lack of structured training and institutional support for faculty makes it difficult to design and deliver engaging, interdisciplinary STEM lessons. Addressing these challenges requires targeted professional development, robust digital infrastructure, learner-centered instructional strategies, and continuous curriculum enhancement to ensure effective and sustainable integrative STEM education.

1.25 Scope and Motivation of the Research

The research aim is to identify the factors that influence the effectiveness of integrative STEM education in Vietnamese high schools. The scope encompasses to examining the effectiveness of online training for teachers, analyze the feature selection performance, assessing self-reports to teachers and addressing the related challenges for the student, teachers and the quality control. The motivation of this research is to prepare the students to modern workforce, improving educational resources, boost teacher proficiency, addressing educational gap, bridge educational disparities, and practices, and encourage innovation and progress.

This research aims to assess the various factors that impact the effectiveness of integrative STEM education in Vietnamese high schools. Specifically, it focuses on evaluating the effectiveness of online training for both teachers and students, the quality of teacher training programs, the accuracy of pre-service teachers' self-reports on their STEM knowledge, and the influence of feature selection on the performance of educational models. This study is motivated by the need for supplying students with the necessary skills for the contemporary job market, bridge educational disparities, boost teacher proficiency, improve educational materials, provide guidance for educational policies and practices, and encourage innovation and progress. The project aims to discover these elements in order to improve STEM education results, eventually leading to the development of a highly trained and inventive workforce in Vietnam. To achieve these objectives, the research employs a mixed-methods approach, combining quantitative data analysis with qualitative insights from teachers, students, and educational administrators. Surveys, interviews, classroom observations, and analysis of academic performance data are utilized to identify key factors influencing STEM learning outcomes. The study also examines the effectiveness of digital tools, online learning platforms, and instructional strategies in enhancing both teaching quality and student engagement. By systematically evaluating these aspects, the research seeks to uncover gaps in current practices, highlight areas for improvement in teacher preparation and professional development, and recommend strategies for integrating technology and interdisciplinary methods effectively.

1.26 Research questions

Our study intends to provide answers to the following questions in order to fill in the gaps that have been found and accomplish the goals of the research:

1. What specific factors influence the quality of teachers in delivering integrative STEM education in Vietnamese high school?
2. How can professional development training programs for teachers be improved to better support integrative STEM education?
3. How to improve the school management, available of resources, infrastructure?

1.27 Research objectives

The main objective of this study is to determine the characteristics that influence the effectiveness of integrated STEM teaching in Vietnamese high schools. The primary contribution is,

- To assess the efficacy of online training for both instructors and students in the context of integrated STEM education, taking into consideration the restrictions of time and the issues that occur.
- To conduct an assessment of the training that teachers get in the STEM education.
- The purpose of this study is to investigate the reliability of pre-service teachers' self-reports about their understanding of STEM in the classroom.
- The purpose of this study is to evaluate the feature selection techniques that may improve the performance of the model in STEM education and the accuracy of its predictions.

1.28 Thesis Organization

The organization of the thesis in which each chapter is explained as follows,

Chapter 1- Introduction: This chapter provides the basic information on STEM Education. It includes the architecture of STEM education. The challenges and application of STEM are illustrated in this chapter.

Chapter II-Literature Survey: This chapter provides background information on STEM education. Further it surveys the works related to the STEM education.

Chapter III-Research methodology: This chapter briefly discusses the design of the Factors impact the Effectiveness of Integrative STEM Education model proposed for Vietnamese high school .

Chapter IV- Results and discussion: In this chapter, we discuss the proposed work's numerical outcomes. The simulation setup, comparison analysis, and study summary are the three sections that show how the proposed work outperformed the prior art in terms of the various performance indicators used.

Chapter V- Conclusion: This chapter offered the thesis's conclusion by outlining all the methods used to achieve the goal. It also highlights the upcoming work that enhanced the suggested work's performance.

Chapter 2

Literature Survey

This chapter provides background information on STEM education with its architecture and characteristics. Is also classifies the targeted teacher training and online experiences of STEM education. Furthermore, it surveys the works related to the effectiveness of integrative STEM education system. STEM education integrates academic concepts with real-world lessons to connect schools, communities, workplaces, and global organizations. Students apply technology, science, mathematics, and engineering skills in specific contexts. To solve the problem of real-world application through the intertwined and interrelated communication, and student learning though experience. Achieving success future careers STEM education system imparts students soft skills such as interaction, grouping, problem solving, innovation, and analytical thinking. Its ability to equip students with the necessary abilities for the contemporary job market STEM education, which combines the disciplines of science, technology, engineering, and mathematics, is gaining worldwide recognition. Which involves a strong focus on incorporating STEM education into the high school curriculum, this section offers a comprehensive analysis of the present trend in many nations. Modern workforce makes STEM education a critical component of contemporary curricula. Research indicates that effective STEM programs not only enhance content knowledge but also foster essential 21st-century skills, including collaboration, creativity, critical thinking, and digital literacy. Teacher preparedness is a central factor in the success of STEM education. Targeted teacher training programs both pre-service and in-service play a significant role in developing educators' content knowledge, pedagogical skills, and confidence in integrating interdisciplinary approaches. Online and blended learning experiences have become increasingly relevant, offering flexible, scalable, and interactive platforms for professional development.

2.1 Introduction

To create connections between educational institutions, local communities, businesses, and international organizations, STEM education integrates theoretical concepts with pertinent real-world teachings. Students apply their expertise in the fields of STEM, under specific conditions. To solve practical, real-life challenges students engage in experiential learning by utilizing interconnected and integrated communication. As a part of the STEM education system students are taught soft skills, like ability of working together, problem solving and creative thinking. In order to be successful in their future employment these abilities are essential for students. The integration of STEM education into high school curricula is becoming more important, not just in Vietnam but also in many other nations. This approach goal is to provide students with real world learning experiences that bridge the academic disciplines and promote critical thinking, problem solving and the innovation. STEM education in Vietnamese high schools strives for traditional subjects, fostering connections among different fields and emphasis real-world application. From building framework volcanoes to design robotics, student engages in hands-on activities that encourage them to apply their knowledge in the significant way. This integration not only improves the understanding of scientific and mathematics concepts and also it cultivates the skills to need for future careers in STEM. However, the efficiency of integrative the STEM education depends on numerous factors.one of the crucial aspect is the quality of education and the extent to which aligns with the aim of STEM education. Furthermore, the availability of resources, teacher training, curriculum development and support from educational authorities that plays the significant role in determining the success of STEM program in high school.2.2 Application

2.2 Related Works

In the article, the authors describe a novel approach to the design of mobile robots that are connected with Android OS tablets. This approach incorporates user interface displays, "voice control models," and "AIDL (Android Interface Definition Language) IPC (Inter-Process Communication) interactive" models for "remote control." Through their investigation of the mobile robot that makes use of the "Rock Chip AI Processor

RK3399Pro," they are primarily concerned with gaining an understanding of the structure and operation of the AI Processor that the Rock Chip robot employs (Tran et al 2022).

To analyze the academic performance of students (Alhazmi et al 2023), the present research utilizing the data mining process. To assess how much a student's initial performance influences their grade point average the study uses a variety of clustering techniques and categories. A part of the T-SNE (t-Distributed Stochastic Neighbor Etc.) technique that is utilized from the proposed dimensional reduction technique.

To examine the correlation between the parameters and enhancing the academic achievement is the main goal of this research. Including admission scores from introductory courses, "academic achievement tests (AAT), and general aptitude tests (GAT)", to reach this goal, many beginning elements are taken into account. To predict the beginning accomplishment of students, this work centers on a categorization methodology that utilizes many factors, such as academic performance and admissions test scores. The project will use machine learning to run trials on many models to find the best effective categorization strategy.

The authors of the study conducted at Hung Yen University of Technology and Education in Vietnam explain the goal, plan of action, and challenges related to digitization at institutions located in low- and middle-income countries. Researchers discuss the "digital shift" that is occurring in the field either locally and worldwide, as well as some of the characteristics associated with higher education in Vietnam, all within the framework of this trend.

Influenced the choice of male and female students to pursue STEM courses at TVET institutions the main goal of this research is to ascertain the different factors, both positive and negative. To examine a cohort of twenty first-year students enrolled in a Technical and Vocational Education and Training (TVET) institution situated in a rural region of Mpumalanga province the present study used qualitative methodologies and focus groups. In addition, a theme-based approach was used to analyze the information gathered.

To seek STEM education, this study concluded that a combination of both pulling and pushing factors had a role in motivating individuals from both male and female TVET colleges. Educational institutions that provide technical and vocational education and training (TVET) must use a learning and teaching approach that is rooted in African culture (Chauke et al 2022), in order to comply with the conclusions of this research. The objective of the current suggestion is to function as a recommendation for legislation.

The purpose of this study is to examine the effect that such an incorporation has to determine the extent to which the incorporation of scientific techniques into STEM training that is focused on projects has an impact on the development of preservice technology teachers' cognitive structures for engineering design thinking. To creating scientific and technical designs in activities that entail using technology (Lin et al., 2021), to assess the cognitive abilities of novice technology teachers and their approach.

Through the utilization of expert polls that are constituted of PBL specialists with knowledge gathered from the current body of literature, this study endeavors to accomplish its objective of offering a set of suggestions for the introduction of a "PBL approach to STEM teaching" in schools. According to the findings of the research conducted by (Smith et al 2022), the four fundamental principles of Problem-Based Learning (PBL) are as follows: flexible knowledge, skills, as well as capacities; advantageous and active "mental processes reasoning"; inherent motivation-driven cooperation; and concerns that are deeply rooted in rich and practical situations. It is feasible that the findings of the study may provide based on evidence support for teachers who are advocating the benefits of utilizing a PBL method in "school-based STEM" teaching. This is something that is feasible.

The purpose of this research is to analyze the ways in which these concepts communicate with others, in addition to the manner in how confidence mediated or serial-mediates the ambitions of students to become entrepreneurs. For the aim of this investigation, a questionnaire was sent over the internet to a total of 394 pupils who were enrolled in postgraduate and undergraduate programs at institutions in Vietnam. The study demonstrated that entrepreneurship Self- efficacy (ESE) has a secondary impact on entrepreneurship Intentions (EI) through the processes of Subjective Norms (SN), Considered Behavioural Control (PBC), nPow, and PA that the same time. This is besides to the direct effects that ESE has on the components of the Theory of Planned Behaviour (TPB) and the need for power (nPow). PBC was the element that had the most significant influence on ESE, while ESE had an indirect influence on the emotional intelligence of students.

No research has yet integrated the "social learning theory, TPB components, and motivation theory of entrepreneurship" into a single model to determine the collective influence of these three theories on emotional intelligence, specifically in Vietnam (Maheshwari et al 2022). The study introduces a novel model of entrepreneurship to evaluate student emotional intelligence, making a significant addition to the existing body of research in Vietnam.

A qualitative study was conducted to investigate the needs for professional development (PD) among teachers working in elementary schools in Vietnam. The investigation was carried out with the participation of ten teachers from ten primary schools located in a large city in Vietnam. Comprehensive interviews with the instructors are included in the data. Insightful insights into the perspectives of instructors about professional development (PD), frequent PD practices, and needs were obtained by qualitative analysis of interview transcripts. All of the teachers believed that professional development was essential for their demanding teaching professions. Programs and activities for professional development were made available by their schools, as well as by the province and district departments of education and training (Nguyen et al 2022). They participated in a variety of online forums for PD for educators. In light of the adjustments to the curriculum, the teachers want more professional development programs and activities. Particularly noteworthy is the fact that they choose work-related, practical professional development courses. In addition to that, they liked participating in hands-on activities and connecting with instructors and professors.

An evaluation of the knowledge, talents, and attitudes of Vietnamese pupils on global citizenship is included in the dataset (Nguyen et al 2021). Experts and consultants adapted the questionnaire to Vietnam's educational environment by using the main learning goals for global nationality education of the “United Nations Educational, Scientific, and Cultural Organization (UNESCO)”, as well as standards, scales, and aspirations for global citizens. When conducting the survey, cluster sampling was used. There were a total of six provinces and cities selected to represent Vietnam's three economic and social regions. In each city or province, three districts were selected to represent the positives and drawbacks of the situation. Every school district included one primary school, one lower intermediate school, and a single upper high school that took pleasure in the examination. In May of 2019, a total of 2069 students took part in the survey. This included 679 students from primary (4 and 5), 673 students from lower (9), and 717 students from upper (10 and 11). In this section, the "mean, standard deviation, lowest, maximum, and range of students' perceptions, attitudes, and actions regarding global citizenship education topics" are shown.

This study originally investigated the technical obstacles that prevent the implementation of Smart Education Systems (SES) in developing countries. An independent "SES framework, vSmartEdu" is made available to users. The plan calls for the implementation of a "hybrid online/offline web-service paradigm and Service-Based Architecture (SBA)" in order to construct intelligent classrooms. For web-based classrooms that have access to the Internet, the online mode is now functioning. When there is no Internet access in a classroom, the "offline-version" of the system is used and filled with students. In conclusion, a prototype was used in order to get feedback from students and instructors with varying degrees of expertise. Both the advantages and the practicality of the solution are shown by the results of the trial installation and assessment (Pham et al 2021).

This research aims to explore the manners whereby students reported teacher teaching styles and scientific attitudes influence their performance on the science test in "four high-performing countries/economies: Hong Kong, China, Canada, and Finland." Through the study of these locations, it is possible to uncover parallels and differences between high-performing educational systems in the field of science and various cultures (Lau et al 2022). The most accurate predictor of achievement across all domains is enthusiasm in scientific learning. The pupils from the West had a greater sense of self-efficacy and performed better than the students from Hong Kong and China. Instruction that is both direct and individualized boosts both the enjoyment and performance of scientific learning.

A study was conducted to investigate the mobile learning behavior of rural high school STEM students, as well as their parents and teachers. The study was titled "High School's Acceptance of Mobile Learning Idea." The Technology Acceptance paradigm serves as the foundation for the "mobile learning model" used in high schools. "550 survey participants" were chosen by the use of stratified random selection. 417 valid questionnaires were examined using a technique called "partial least squares structural equation modeling." The model was able to explain the acceptance of mobile learning by students, educators, and parents by a percentage of forty-eight percent (Mutambara et al 2021). Behavioral intention was directly influenced by the original TAM (Technology Acceptance Model) components, which also mediated the relationship between those components and external factors. Based on the findings of the multigroup study, there were three distinct paths that were significantly different for both parents and students. There was not a substantial difference between any of the paths for either the students or the teachers.

Research and teaching in the STEM fields are now a phenomenon that occurs on a worldwide scale. There is a lack of synthesis techniques for teaching the interdisciplinarity of STEM education, despite the fact that STEM education is crucial. It is possible that this lack of consistency may hinder the theory of STEM education as well as fresh contributions. This study presents a theoretical framework for STEM education, with the goal of bringing together different teaching methods and approaches to the integration of disciplines (Aguilera et al 2021). In order to investigate the digital creative growth of Vietnamese high school pupils, the "Serendipity-Mindsponge-3D (SM3D) knowledge management framework" is used. Through the use of "Bayesian Mindsponge Framework (BMF)" analytics on "UNESCO's dataset" consisting of 1061 observations, they came to the conclusion that digital capability and sincerity are factors that contribute to the digital creativity of high school students. There is a moderated relationship between autonomous learning and digital innovation when there is support from both parents and teachers. There is a correlation between children who are encouraged by their parents and teachers to study and explore online and greater digital creativity (Nguyen et al 2023). Self-learning is connected to this. When individuals do not have the assistance of their parents or instructors, self-learning might lead to a decrease in digital inventiveness. Based on these findings, it seems that digital creativity may be encouraged via the use of digital devices, the openness of the Internet, and autonomous study with the assistance of both personal and academic resources.

"STEM higher learning in the United States" has long been seen as a place where women, members of minority groups, and students and scholars from other countries are not welcome. In order to empower minority students who are underrepresented in "STEM higher education," humanizing strategies acknowledge the challenges that individuals face and the national capital that they bring to their education. A "STEM education" that places an emphasis on the humanity of students has the potential to cultivate justice, well-being, and flourishing in addition to the development of data and abilities. Next, they provide a framework for visualizing the biome in which undergraduate students who are majoring in STEM fields are immersed. Furthermore, they stress the individual and cooperative duties that ecosystem members may play in the process of humanizing STEM education (Yao et al 2023).

Table 2.1: Summary of Existing work

Reference	Methods or Algorithms used	Limitations
(Tran et al 2022)	Designing mobile robots that are integrated with Android OS tablets	They will continue to gather data to develop the speech processing model to manage mobile robots, notably the Korean language, which has just 87% confidence.
(Alhazmi et al 2023)	Academic achievement tests (AAT), and general aptitude tests (GAT)	They want to increase prediction performance using deep learning architectures. It may blend academic and non-academic characteristics.
(Quy et al 2023)	"Digital transformation" in higher education	Digital transformation changes thinking and

		managerial ability, especially for students, professors, management, and administrative personnel.
(Chauke et al 2022)	TVET Colleges	The data were obtained from 20 people initially. Thus, the research conclusions cannot be applied to all South African TVET college STEM students.
(Lin et al 2021)	Preservice technology teachers'	Implementing the flow-map technique with the concept of "metalistening is laborious" presents challenges in expanding the size of the research participants. The primary limitation of this study is in its capacity to be applied to a wider population.
(Smith et al 2022)	Expert Wisdom and Research to Frame Educational Practice	However, they feel the carefully selected foreign participants offered a wide spectrum of experience and opinions.
(Maheshwari et al 2022)	Social learning, human motivation, and TPB.	This cross-sectional study only covers one time period, hence a longitudinal study is

		needed to track entrepreneurship growth over time.
(Nguyen et al 2022)	Professional development (PD)	Challenging in the classroom activities.
(Nguyen et al 2021)	UNESCO's	In-depth data studies may also uncover demographic, family, and school characteristics that may impact children' global citizenship knowledge, abilities, and attitudes.
(Pham et al 2021)	Smart education system (SES)	Lack of AI integration for user action prediction and recommendation.
(Lau et al 2022)	Multi-level analysis	Many additional elements, like demography, school scheme, education policy, scientific education value, and teacher preparation, should be explored.
(Mutambara et al 2021)	Mobile learning idea	Limited in rural high schools.
(Aguilera et al 2021)	STEM	Limited in creating a reliable STEM literacy to pupils.

(Nguyen et al 2023)	Serendipity-mind sponge 3D-(SM3D)	The proposed method efficiency has not been fully validated.
(Yao et al 2023)	STEM Higher learning in the education system.	This method ignores the reformer's lived experience and how it might improve STEM undergraduate student outcomes.

This paper presents a novel model using machine learning methods to forecast the final test scores of undergraduate students, use the midterm test results as the input data. The forecasts were based only on three parameters: midterm test marks, Departmental and faculty-related data. Data-driven studies are essential for the development of an educational analysis methodology in college or university and for assisting in decision-making processes. This approach offers a crucial contribution to the early detection of pupils who are very likely to fail and identifies the most efficient machine learning techniques (Yağcı et al 2022).

The main goal of STEM instruction is to foster students' passion for careers in STEM. It is reasonable to suppose that there is a correlation between students' stereotyped perceptions about STEM occupations and their level of enthusiasm in following such occupations. Nevertheless, there is a dearth of research investigating the extent and manner in which students' inclination towards STEM jobs is whether directly or indirectly shaped by their stereotyped ideas (Luo et al 2021). This research examined the relationship between upper primary students' stereotyped ideas about STEM occupations and their levels of STEM self-efficacy and STEM career-related result expectancies. Additionally, the study explored how these factors influenced the students' motivation in pursuing STEM careers.

It is difficult to change STEM higher education culture in a way that is more inclusive and supports more students in pursuing STEM jobs. In this document, will outline a novel approach to transforming higher education in the fields of STEM education system. The suggested paradigm is named the Sustainable, Transformational Interaction across a Multi-Institution/Multidisciplinary STEM fields, or STEM², Network. The internet connection embraces a paths paradigm, rather than a pipeline one, for entering STEM careers. The foundation of this study is based on three robust theoretical frameworks: Societies of Transformation, design of systems for change in organizations, and the resulting effects on the spread of innovative practices in STEM schooling. The Network today consists of three commercial 4-year institutions and two public local colleges. Utilizing the close geographical proximity and shared characteristics of learners, this approach facilitates transformation across several levels, including the classroom, disciplinary, institutional, and inter-institutional levels (Santangelo et al 2021).

The author proposed a conceptual framework for the effective integration of STEM education, based on the concepts provided in the Japanese curriculum (Yata et al 2020). The conceptual framework suggests that an approach to improve STEM education is to uphold the core principles of STEM education system within the realm of engineering. The crucial aspect of implementing STEM education is to analyze and create the optimal sequence and blend of the learning process and activities, guided by the suggested conceptual framework. While this framework is theoretical, it could prove helpful in establishing an appropriate approach to STEM education and elucidating the connection between STEM technology and classroom education.

This post seeks to explore a comprehensive framework that encompasses the notion of integrated STEM teaching. The study focuses on four distinct collaborative methods of instruction that provide the fundamental theoretical framework for bridging borders. The essay proposes a collaborative pedagogical framework and a temporary declaration that identifies the key elements that support the advancement of a boundary-crossing STEM teaching (Leung et al 2020). The elements that make up this setting consist of learning, community of practices, solving problems, learning collaborative operations, and boundaries objects.

This study developed and validated the TRi-STEM, an investigation instrument specifically intended to evaluate teachers' readiness in instructing STEM courses. The investigative and confirming techniques demonstrated strong psychometric properties, as well as high reliability scores. The exam is appealing to the Greek population and has 24 questions, categorized into four dimensions: mental, psychological, self-worth, and commitment. Facts regarding validity and reliability strong internal consistency, as well as measurement invariance, indicate that the suggested scale has reliable psychometric qualities and could be effectively used in research. TRi-STEM is a reliable tool for accurately assessing teachers' preparedness, enabling research on the variables that influence them, and supporting intervention programs that attempt to implement educational changes related to the incorporation of knowledge into novel curriculum. The desired cultivation goals and the precise circumstances in which they will be used this tool might serve as a prototype for creating novel devices that may differ in certain features depending. The utilization of "TRi-STEM" questionnaires in instructive investigate can help predict the success of STEM educational reform and support studies on teachers' profiles and needs in STEM implementation. This information can be used to organize appropriate training programs and interventions (Papagiannopoulou et al 2023).

A theoretical foundation for STEM education is presented in this article. The first step is to ascertain the pedagogical (founded on Situated Learning Theory and co-teaching) and epistemological (depending on the Model of Educational Reconstruction and General Systems Theory) alignments. A pedagogical model is then put out to assist with the application of the STEM approach in the classroom once these difficulties have been recognized (Aguilera et al 2024). The Initial, Deconstruction, Explanation, Application, Review, and Reporting phases comprise the six stages of the IDEARR approach, which is designed to tackle problems that are not well defined. The final section of this article offers a reflection on the educational implications of using this theoretical framework to work on STEM education in classrooms, especially those concerning the setup and management of educational institutions and the initial and continuing professional development of teachers.

The current study examined the institutional structures that hinder the professional advancement of early-career Women of Color in STEM academia (Woods Jr et al 2024). Using structuration theories and Critique Race Feminism as frameworks for thinking, attendees discussed the impact of legislation, procedures, and guidelines on the recruitment, labor, and advancement of early-career Women of Color professors in STEM fields. The cold environments brought about by systematic oppression are explained by research on Women of White faculty in STEM, but the present qualitative investigation found serving specific ways that unclear deadlines, ambiguous policies, and unequal workloads jeopardize the career accomplishments of early-career Women of Shade faculty in STEM.

The present study details the first phases of creation of "PlatypOUs", an open-source mobile robot platform that can be remotely controlled using an "Electromyography (EMG)" instrument (Rácz et al 2022). The "MindRove brain-computer interface (BCI)" gear works as a sensor in this technique to get signals. The acquired bio-signals are classified using a "Support Vector Machine" (SVM), and the resulting output from the SVM is then transformed into motion instructions for the handheld device. In addition to the tangible mobile robot platform, an open-source 3D robotic simulator called Gazebo was used to create a virtual environment within the Robot Operating System (ROS) architecture. This virtual ecosystem has the same functionalities as the physical platform.

The study's conclusions highlight the value of integrated, as opposed to silo-based, explicit STEM education. The finding has significant ramifications for future research and preservice teacher training programs. First and foremost, it is crucial for STEM instructors to modify their initiatives in order to include clear and specific learning possibilities that aim to enhance the knowledge, skills, and attitudes of pre-service teachers (PSTs) in the field of STEM given the growing need for integrated STEM training. Second, it's critical that PSTs see integrated STEM training in action and have experience teaching it during field trips in order to guarantee the intended shift in attitudes regarding STEM. Preservice teachers often see STEM was a “paradigm shift" and could be hesitant to communicate it until they observe real-world examples of integrated STEM learning in action (Menon et al 2023).

This essay aims to elucidate the process of digital evolution in higher learning both in Vietnam and globally as well as to examine certain features of higher education in Vietnam that are involved in the digital transformation process (Quy et al 2023). Moreover, analyze the vision, plans, and challenges related to digitization at universities in low- and middle-income countries, specifically from the perspective of "Hung Yen University of Technology and Education in Vietnam".

This research aims to show how students' reasons for selecting books—whether they are recommendations or personal preferences—drive their interest in reading, how different thinking pathways motivate those who are low and high academic achievers, and how residence scholarly cultures enhance book-reading interest (Vuong et al 2021). Applying Bayesian analysis to a dataset of survey responses from 4966 Vietnamese secondary students (aged 11 to 15 years, sixth to ninth grade), we discovered the following: (i) parental book reading activities (parents reading books to their children) and book recommendations are positively associated with reading interest; (ii) high-achieving students are more interested in reading books if they are allowed to select the books based on their own preferences; and (iii) parental book reading activities can promote book reading interest by understanding children's preferences as well as through recommendations.

This study examines the combined effect of adopting Inquiry-Based Science Education (IBSE) via well-designed inquiry experiments across STEM fields, aided by digital technologies and preliminary evaluation tools, and conducted by professionals with specialized training in this field. The study utilized a written inquiry capability test as its main research tool and investigated the influence of IBSE deployment on the advancement of certain inquiry abilities before and after a period of consistent utilization (Ješková et al 2022). The study was conducted using a quasi-experimental design. The research findings showed that the sample of 2307 upper middle school pupils had a poor level of inquiry skills at the beginning. However, there was a statistically significant improvement in students' inquiry abilities, with a medium-sized effect.

In order to better understand how these strategies and obstacles impact STEM education in the nation's high schools, this research set out to investigate the experiences of STEM teachers working in high schools in Qatar. It focused on the pedagogical techniques these teachers use as well as the difficulties they face. The research employs an observational approach and gathers data using a survey administered to 299 STEM instructors in secondary high schools (grades 11 and 12). This research looked at the obstacles high school instructors believe stand in the way of their students' successful STEM learning. The results of the research indicated how school- and student-related variables shaped STEM instruction. Based on the instructors' age group, gender, grade level of instruction, and university degree, significant variances were found. According to logistic regression analysis, instructors' age group and level of university education have an impact on how likely they are to use STEM pedagogies in the classroom (Sellami et al 2022).

This research examined the STEAM activities implemented by instructors in their classes during the 2017–2018 academic year in the northern region of Osmaniye, Turkey. The fourth-grade kids were enrolled in elementary schools (Uştu et al., 2022). The instructors, the inside researcher, and the evaluators all worked together to monitor and reflect on the integration process, which was broken down into four phases: planning, implementing, and evaluating the activities. During the study, many multidisciplinary models of integrating art with different fields were identified, as well as a few useful examples of art incorporation in planning and implementation.

Within the context of STEM schooling, the significance of the teaching of engineering has expanded. New educational methods, such as the "National Research Council's Framework" of K–12 Science Instruction, consider engineering techniques to be essential components of a robust STEM education. The concept of developing a series of protocols akin to those employed in engineering firms is consistent with contemporary viewpoints in STEM education research. However, current approaches, such as the NRC Framework, appear excessively dependent on and closely adhere to the catalogue of scientific procedures. This paper presents a novel collection of engineering methodologies that seek to capture the nuanced aspects of knowledge that differentiate engineering from scientific. It builds on the NRC's Framework. The nine engineering practices—which include crucial elements like problem scoping, finding various solutions, choosing, testing, and refining solutions, as well as materializing solutions—have epistemological subtleties that are absent from other approaches. This epistemic approach may help students absorb knowledge and enhance their critical thinking skills while providing a more thorough and grounded understanding of the STEM fields (Simarro et al 2021).

This research used Bronfenbrenner's socio-ecological model and the theoretical concept of resilience to investigate how STEM professors in postsecondary education reacted to changes in academic roles and curriculum. The two-year case study included 32 STEM higher education professors and leaders. Semi-structured interviews were used for data collection, and the results were theme-coded and inductively analyzed (Ross et al 2022).

The objective of this research was to gather data (Belbase et al 2022) in order to get a deeper understanding of the current state of integrated STEAM education. To develop ideas and topics related to the opportunities, priorities, procedures, and issues of STEAM education, they first did thorough research of the literature and then an analysis of the documents. The investigation of STEAM educational ideas in the research resulted in the identification of three components: the potential of the STEAM activity, the purpose of STEAM training, and the benefits of STEM instruction.

The objective of the present study was to delineate gender stereotypes and incremental beliefs (i.e., the belief in the potential for change) in connection to a wide range of skills traditionally associated with males and females (Moè et al., 2021). A total of STEM pupils non-STEM students from three European countries, which were ranked as top, middle, and bottom in the Global Gender Gap Report, participated in the study. Gender stereotypes and incremental beliefs were assessed using questionnaires for self-report. In addition, a verbal speed test and an intellectual rotation task were performed. In the country with the most pronounced gender discrepancy, men had a higher propensity than women to endorse stereotypes that favoured males, while women shown a greater inclination than men to accept stereotypes that favoured females.

Aside from drawing from structures for research and disciplinary identities, the present research tested both expanded mathematical models of STEM identities. It also included factors related to identity development such as race, ethnic background, involvement in science discourse, parental education, and at-home research support (Dou et al., 2022). This study used a sample of 522 undergraduate students engaged in introductory STEM courses at a Hispanic Serving Institution to investigate the relationships between interest, sense of acknowledgment, performance-competence, and identity within the STEM setting. The findings confirm the assessment of STEM identities and its indicators, providing researchers with a predictive model associated with academic aspirations in various STEM fields.

2.3 Vietnamese Education System

The Minister of Education and Training of Vietnam said that Vietnamese families are willing to make significant sacrifices, such as selling their farms and homes, in order to invest in their children's education. This commitment is believed to be a contributing factor to the high accomplishment of Vietnamese students in the 2015 Program for International Student Assessment (PISA) test.Although Vietnam has a lower GDP, the PISA statistics from 2012 to 2018 consistently demonstrate that Vietnamese students outperformed students from other nations on average. In order to get these outcomes, families have paid around 24% of the overall education expenditure. In Vietnam, the education expenditure per person is 12% of the total GDP per capita.

This research aims to enhance the current efficiency assessment technique by using "Data Envelopment Analysis" (DEA). The main objective is to determine standards that are pertinent in terms of the required quantity of inputs and results for enhancing performance (Le et al., 2021). The proposed inverse optimizer seeks to ascertain the required expenditures for family education across provincial school systems, while considering different levels of efficiency. This is done while ensuring that the effectiveness constraint of meeting the university entry threshold for test outcomes is fulfilled. The data strongly support the inclusion of this restriction in the action plans designed to improve educational outcomes in all counties across Vietnam.

The "Grade 11 Organic Chemistry part in the Vietnamese General Education Program" has a significant amount of knowledge that is directly applicable to real-life situations, making it highly ideal for implementing project-based teaching methods. To ensure the effectiveness of project-based education, especially in promoting students' entrepreneurial skills, it is crucial to organize it according to the hybrid educational model. A comprehensive analysis of the organic chemistry section of grade 11 was conducted to provide a list of thirty research themes, each accompanied by specific research difficulties. The topics that were submitted were assessed for their applicability, accuracy, scientific value, and practicability. An idea was proposed to integrate online instructional activities with learning through projects in order to enhance the efficiency of the process. With each participant representing a unique area of Vietnam the efficacy of instruction has been shown by a research conducted at the school. To engage in self-directed learning as a direct outcome of their participation in the research (Dai et al., 2021) the findings indicate a significant improvement in the students' ability.

2.4 Students' performance prediction in High school

The use of data to forecast academic performance in higher education institutions advancements in big data analysis and artificial intelligence have enabled. Various studies have been performed to explore the use of pupil educational and personality traits in classifying and predicting their future performance, using contemporary machine learning and statistical techniques. This article proposes the use of machine learning techniques to enhance the precision of predicting pupil achievement by using data that is available before the start of the school year. This would enable the implementation of proactive measures. To improve the STEM skills of secondary school students, this study combined the "Conceive-Design-Implement-Operate (CDIO)" paradigm with the "Engineering Design Process (EDP)", creating a new approach called EDP-CDIO. Subsequently, it juxtaposed the outcomes of this approach with the conventional CDIO methodology. The inspection of artifacts was used, whilst quantitative data was gained via the administration of a test both before and after the test this gathers qualitative information, and informal interviews. The EDP-CDIO model significantly improved students' STEM knowledge, talents, and attitudes the results of the repeated-measures analysis of variances and conceptual network analysis showed compared to the traditional CDIO approach. It additionally assisted students in developing wider philosophical connections in STEM competence.

The integration of the EDP-CDIO paradigm into their instructional methods, especially when used using an iterative design methodology this research provide valuable guidance for K-12 STEM instructors, recommending (Xi et al., 2024).

Based on study by Tytler et al. (2020), the six main parts of the education in the STEM fields system are: curriculum for themes and processes, educational policy, curricular evaluation, effective teaching, and teacher training. More specifically, the existence of one component is contingent upon the presence of the other. The essential elements of STEM education consist of a curriculum focused on specific topics and activities, together with highly competent teachers. Assessment functions as the fundamental premise, while progress for teachers serves as the needed assurance. All six of these elements work together to advance the STEM education system by interacting with each other in various situations.

This included the use of openended inquiries that were analyzed qualitatively utilizing AL CESTE, along with a condensed form of the "Expectations and Values Questionnaire" (EV Q) that was evaluated. The research undertaken by (Rodríguez-Naveiras et al 2023) investigates individuals' views towards mathematics and employment in STEM fields, while also exploring gender disparities and classifying intellectual capabilities into two distinct groups: high-ability or conventional competence. Given the many approaches used in the investigation, a mixture of strategies was employed.

The author of (Dotterer at al 2022) looked at the relationships between parent participation and the STEM self-efficacy, utility, interest, and success of minority students using data from the High School Longitudinal research: 2009 (HLS: 2009). In MPlus, concurrent and longitudinal models were used to investigate the relationship between parent participation in the ninth grade and STEM performance and interest, both directly and indirectly via self-efficacy and utility. Concurrent models demonstrated a substantial relationship between parental participation in STEM and adolescents' STEM self-efficacy, which in turn demonstrated a significant relationship with STEM interest and accomplishment.

In this study, Dutch teachers of the relatively new STEM subjects O&O and NLT (nature, life, and technology) filled out a questionnaire to gauge their opinions regarding overseeing research activities and design projects in secondary education. These project- and context-based integrated STEM courses are offered in a select few schools. The student and instructor populations in these integrated STEM topics varied significantly: While O&O is offered in years 7–12 and may be taught by any secondary school teacher, NLT is taught in grades 10–12 by instructors who are certified in a scientific topic (Vossen et al 2021).

In this research, the teaching beliefs of new teachers served as a mediator to examine the long-term consequences of their training experiences on their perceived competency as instructors. Data were gathered for the research from 219 novice instructors in various K–12 institutions in China. The results demonstrated a favorable relationship between STEM instructors' views of their own teaching competency and their knowledge training, teaching practice, and teaching beliefs during teacher education programs. The association between perceived teaching competence and practice was mediated by teaching beliefs (Song et al 2021).

The author of (Hackman et al 2021) presents unique research on the attitudes of liberal science instructors. It aims to clarify and understand the current beliefs that science teachers have about STEM education and to pinpoint the variables that may have an impact on these beliefs. In order to investigate perceptions toward STEM teaching between in-service science teachers, a questionnaire was created. This was further supported by interviews with ten scientific instructors. Regarding their overall attitude ratings, science instructors in private and public schools differed significantly. Teachers from various grades showed a somewhat significant difference. Regression analysis results indicated that science teachers' views toward STEM education are favourably influenced by peer cooperation, STEM exercise, specialized and managerial support, and instructional time.

The purpose of the (Hamad et al 2022) research is to investigate how science instructors feel about incorporating STEM methods into their instruction. Furthermore, the study delves further into the obstacles faced in this area to illuminate contemporary STEM practices in the situation of the "United Arab Emirates" (UAE). This research is divided into two phases. In the first, semi-structured interviews were used to gather qualitative data and investigate the perspectives and lived experiences of three science teachers who had been integrating STEM subjects into their usual cycle 2 curriculum for more than two years. A closed-ended survey was developed during the subsequent phase to collect data and evaluate quantitative data on teachers' impressions of the "challenges encountered by teachers when implementing STEM teaching" across a broader sample. According to research, science instructors are typically in Favour of implementing STEM-based activities.

The study conducted by Yang et al. (2021) used a validation sample of 193 in-service and 225 pre-service early childhood teachers in Zhejiang, China, to assess the validity of the STEM Teaching Self-efficacy Scale (STSS). The results demonstrated preliminary indications of the accuracy and dependability of the two STSS variables, namely topic confidence and school self-efficacy. To ensure the scale's subject matter and construct accuracy and to include the full spectrum of self-efficacy in STEM education practices, items were created using existing research and selected using component analysis.

Authors of (Barakat et al 2022) specific goal was to find out if younger student populations are more effective at encouraging students to feel more confident in their scientific abilities. In the end, the goal was to get students to see themselves as potential scientists, regardless of their cultural background or socioeconomic status. The "Draw a Scientist Test" (DAST) and a generic "Science Interest Survey" were both completed by students who took part in the program. The DAST was administered both before and after the event. Following their participation in the Youth Science Program (YSP), students exhibited more favorable views toward STEM fields, as well showed a notable increase in the proportion of pupils who sketched scientists who were similar to them or other members of their neighborhood. This was demonstrated by the statistical examination of the numerical information collected from this equipment.

The objective of this article is to provide a framework for a cohesive STEM identity for educators, aiming to establish a robust description that may be used across many educational contexts. Elementary school teachers have numerous identities, including those of STEM learners, professional educators, and innovators in STEM education. This model depicts the conflicts that arise between these identities. As per proposed model, the complexity of these roles is organized via the interlacing of elements from present theories of STEM student identity and an educator's identity. The purposeful cultivation of integrated STEM personas has a chance to enhance teacher preparedness by fostering the ability to not just try but also sustain novel curricula. This technique may be used by teacher educators and facilitators of professional development in order to give teachers with more individualized assistance (Galanti et al 2022).

The purpose of this research was to investigate children in upper elementary school on their attitudes of STEM fields by consuming two newly devised specifications. A total of 564 replies that were considered to be legitimate were gathered from students in grades four through six. These findings were obtained by the use of a redesigned version of the "Draw-A-Scientist Test", which was published in Chambers in Science Education 67(2):255–265 in 1983. For the purpose of ensuring that the information is reliable, students sketches and written assessments of the STEM experts work were subjected to content assessment utilizing the newly developed criteria and a categorization approach. In addition, the inter-rater accuracy was assessed. As a result of the findings, it was found that both male and female scientists, engineers, and technicians were more likely to be male than female. Furthermore, students exhibited a propensity to associate scientists with laboratory-related attributes, engineers with building development, and technicians with technical objects. Students' perceptions of engineers, technicians, and scientists may be categorized into seven main vocational areas. Moreover, students predominantly include inventors and developers in their displays of physicists and scientists, respectively, not engineers. This finding applied to all three categories of professions (Luo et al 2023).

Table 2.2: Research summary of Vietnamese Education System

Reference	Methods or Algorithms used	Limitations
(Xi et al 2024)	CDIO with the EDP, dubbed EDP-CDIO	Non-equivalent group design Researchers' perceptions on qualitative data from interviews and artifacts could influence findings.
(Hu et al 2024)	Provides insights into the interconnected components of the STEM education system.	Complexity interactions.
(Rodríguez-Naveiras et al 2023)	Qualitatively analyzed using ALCESTE and a scaled-down version of the Expectations and Values Questionnaire (EVQ)	Trouble combining qualitative and quantitative conclusions despite heterogeneous techniques.

(Dotterer at al 2022)	MPlus software	Improving parent participation andSTEM measuring methods to reduce bias and boost validity.
(Vossen et al 2021)	Preservice technology teachers'	Response consistency and dependability may be impacted by differences in the training and experience of O&O and NLT teachers.
(Song et al 2021)	K–12 institutions	The research may not be able to generalize beyond 219 inexperienced STEM educators from Chinese K–12 schools. The results may not apply to other locations or circumstances due to China's educated demographic variety.
(Hackman et al 2021)	STEM education in Liberia	The validity and reliability of the STEM education attitudes questionnaire may affect outcomes. The dependability of survey results may be affected by question interpretation or answer biases like social desirability.
(Hamad et al 2022)	Mixed-methods study utilized semi-structured interviews	Limited sample size.
(Yang et al 2021)	STSS	The STSS might not include all aspects of STEM teaching self-efficacy, and other elements

		affecting self-efficacy beliefs may not have been adequately addressed despite intensive development and validation.
(Barakat et al 2022)	DAST, and YSP	Insufficient use of artificial intelligence for user action prediction and suggestion.
(Galanti et al 2022)	Conceptualizes integrated STEM teacher identity	Limited in creating a reliable STEM literacy to pupils. Limited in rural high schools.
(Luo et al 2023)	Mobile learning idea	The proposed method efficiency has not been fully validated.

2.5 Integrated STEM education system

The purpose of the study (Spikic et al 2022) was to investigate the degree to which student teachers were exposed to six fundamental principles of international science, technology, engineering, and mathematics (iSTEM) education. These principles include "problem-centered learning," "integration of different STEM disciplines," "modeling," "inquiry-based learning," "design-based learning," and "cooperative learning." A multidisciplinary team was used to design iSTEM learning tools.

The key benefits of an integrated approach to neuroscience via the core curriculum, according to the author, will be a learning community that prioritizes cooperation and better support for students' performance in the larger STEM curriculum. The neuroscience core curriculum at Holy Cross is intended to serve as a scaffolded spiral curriculum that facilitates the development of broad-based expertise in basic STEM topics. This is how it relates to the larger STEM curriculum. Students studying neuroscience are now learning STEM principles in courses that are clearly tied to neuroscience, rather than in isolated STEM courses (Basu et al 2021).

A conceptual flow graphic (CFG) was created to represent the structure and sequence of 50 integrated STEM curricular modules. An analysis was conducted to categorize and understand the incorporation and curricular uniformity within each unit by examining the character of the interconnected connections and identifying trends. The units were divided into four primary categories that include combined STEM curricula: (i) science units with tangentially related technological design challenges (EDCs); (ii) units with an emphasis on engineering design but not significantly related to science content; (iii) units with a design-related component and science content acting as a backdrop; and (iv) coherent and integrated STEM units. Every component in the realm of the physical sciences were categorized as being cohesive and coherent, showing a strong conceptual consistency between the main scientific principles and the EDC. Curricula focused on Earth and biological sciences sometimes lacked a robust integration of scientific material with "Engineering Design and Construction" (EDC) components. Alternatively, they relied on the technical design process to provide a unified storyline for the module (Roehrig et al 2021).

The aim of the study conducted by Wahono et al. (2021) is to evaluate the effectiveness of an educational technique that combines socio-scientific issues (SSI) with the STEM-6E framework. Comprehensive STEM instruction may serve as a method to tackle contentious scientific topics, such as genome editing, which is illegal in several countries, including Indonesia. A total of 109 pupils from two distinct junior high schools participated in this experiment.

The collected data was analyzed using a combination of quantitative and qualitative information analytics. In addition, the statistical study used a thorough assessment technique that encompassed both intermediate and distal inspection levels. The research findings suggest that the inclusion of socio-scientific topics in STEM-6E education might lead to a distinct kind of collaboration in the classroom started by the instructor.

The objective of this research (Zhou et al 2023) is to examine the "Solution-based Design Process" (SBDP), who integrates knowledge and teaching of academic subjects by emphasizing the discovery and solutions of real-world problems. Perform a research investigation on judgmental reflection in auto ethnographic design methodology to analyze how an optimized SBDP (Self-Biased Design Process) can improve (i) the design abilities and mindsets of Design-Based Practitioners (DBP) in the field of integrated STEM education, and (ii) the teaching techniques for developing and executing incorporated STEM tasks that incorporate design models. According to this research, the Solution-based DBP has a distinctive characteristic of being connected to the cognitive and logical processes of thinking and reasoning. Its implementation necessitates the proficient use of 3D printing-based digital fabrication. In addition, I showcased a Solution-based Design-Build-Play (DBP) approach, which included using 3D printing-based digital fabrication.

(Zhang et al 2023) article suggests an endeavour to include retro computing into educational programs in order to connect the fields of hardware and software. The main concept is to introduce simple but functional computer systems into educational settings, particularly microcomputers designed for the consumer market that use microprocessor technology from the 1980s. The retro computing activities may be categorized into a three-stage process of collecting, restoring, and building, which requires more advanced knowledge and problem-solving skills at various educational levels, ranging from middle school to college. Introducing retro computing as a pastime provides several advantages

Beyond just providing hands-on experience. These include fostering self-motivated students, lifelong learning habits, and environmental awareness.

2.6 Conceptual framework for STEM education

Incorporating ideas from previous research on educational effectiveness, STEM pedagogy, and organizational management, the conceptual model that was developed for this study on the elements that influence the efficiency of integrated STEM education system in Vietnamese high school was able to include this finding. The concept tries to identify intricate links and factors that contribute to effective STEM educational outcomes by methodically assessing teacher quality, curriculum design, technology integration, and student engagement. The analysis and comprehension of facts This organized method not only guides, but also offers solid suggestions for enhancing STEM teaching methods in Vietnamese high schools.

The study conducted by Roehrig et al. (2021) introduces a fully combined STEM education model that may serve as a unifying vision for educators, scientists, and instructional designers. This discusses the many methods and interpretations of how K-12 integrative STEM education is comprehended and put into practice. The framework builds upon the current integrated STEM research by delineating seven essential characteristics associated with combined STEM: (a) the pivotal role of architectural design, (b) problem-solving motivated by real-world concerns, (c) incorporation of setting, (d) incorporation of content, (e) adoption of STEM practices, (f) cultivation of modern-day skills, and (g) provision of students with information regarding STEM careers. The objective of integrated STEM paradigm is to offer educators more accurate guidance and streamline integrated STEM research. The many components of integrated STEM this research has been hindered by a limited understanding.

Zhou et al. (2022) propose a novel research direction that requires a comprehensive understanding of the appropriate methodologies, skills, and mindsets for integrative STEM instruction. This study introduces a design-oriented conceptual framework which could assist educators in developing a comprehensive STEM curriculum.

Encompassing educators, learners, and experts who serve as external authorities in teaching furthermore, it has the capacity to promote the formation and cooperation of STEM education groups. That integrates design principles with STEM instruction they may collaborate to develop a curriculum.

Included two distinct stages: biosynthesis and VCLE building the study undertaken by (Wannapiroon et al 2022). A collective of 19 specialists contributed to the development and assessment of the framework aside from the academics conducting the study. While an additional ten specialists contributed to its evaluation a total of nine professionals were involved in its development. By synthesizing the information gathered from in-depth conversations and doing further examination of the content the suggested STEAM-imitation strategy was evaluated.

In order to introduce and assess the implementation of 'gamification' procedures the results suggested that the VCLE design should first use a traditional method, such as an in-person classroom environment. The gamification process was moved online and away from traditional classroom settings this was reinforced even more. The gamification process was moved online and away from traditional classroom settings

The elements included in this list are exploration, discovery, connections, creativity, and reflection. The aim of the study conducted by Belbase et al. (2022) was to examine the current state of unified STEAM instruction. Researchers performed a thorough examination of existing literature, and then analyzed documents to identify and develop ideas and topics related to the potential, importance, procedures, and challenges of STEAM education. After analyzing the literature, the investigation of STEAM learning concepts unveiled three components: the STEAM movements, the goal of STEAM schooling, and the benefits of STEM education.

A conceptual framework for assessing the computational thinking skills of primary school kids with the aim of developing impactful instructional situations. The researcher's objective was to synthesize information from studies on computer program activities for children between the ages of zero and eight, and also for pre- & in-service educators working with young children (Alam et al 2022). The aim was to ascertain the possible advantages that robotics programming may provide in the instruction and acquisition of STEM topics. The investigation started with incorporating research articles that were found using search and assessment methodologies. These studies were selected because they all use instructional robotic.

The study conducted by (Christian et al 2021) examined the emotional impacts of engaging in a background in engineering workshop for intermediate STEM teachers, which was part of a 200-hour continuing education program. The workshop focused on integrating electricity and biotechnology principles and design techniques into discipline teaching. It also aimed to prepare instructors to distinguish between various engineering areas and provide guidance on career routes. The workshop design was guided by the conceptual framework of the interconnected model of professional progress. This framework was used to identify the factors that contribute regarding technology; this pertains to the belief in one's ability to teach effectively and the understanding of potential career paths.

Initially, the focus of joint proposals was on fostering student interest and increasing engagement, with the expectation that this would result in students in grades kindergarten through twelve being motivated to pursue STEM subjects (Weinberg et al 2021). Eventually, started discussing the significance of building relevance, such as by including teachings on socioscientific topics, to improve students' conceptual comprehension. Socioscientific challenges are characterized by the absence of definitive right or incorrect solutions. Instead, these questions need the integration of several forms of knowledge, such as natural science, social science, and moral considerations, in order to comprehend their intricate nature. The goal of the (Akour et al 2022) research is to find out how Gulf Coast students feel about the metaverse system as a teaching tool. The theoretical framework incorporates the adoption properties of testing, transparency, reliability, and difficulty, together with users' enjoyment, personal imagination, and the frameworks of the Technology Acceptance Model (TAM). The paper's innovation comes in its conceptual model that establishes a correlation between personal-based traits and technology-based aspects. Furthermore, the present research will use the innovative method of hybrid analysis to conduct “deep learning-based” analysis of “Structural Equation Modeling” (SEM) and “Artificial Neural Network” (ANN). Furthermore, the present research utilizes the Importance-Performance Map Analysis (IPMA) to assess the significance and effectiveness of the elements involved.

Author of (Lavi et al 2021) research endeavors to examine how students at Technion - Israel Institute of Technology, a STEM research institution, are developing their 21st century talents. Designed and implemented an online survey such as 14 distinct proficiencies, which was then sent to around 1500 individuals consisting of both current students and alumni. Students were instructed to evaluate each skill based on the degree to which it was developed over their educational journey. Domain-general skills surpassed both STEM-specific capacities or gentle (connections) skills, while skills surpassed softer abilities.

2.7 Related Hypotheses

Our proposed methodology will be guided by the following hypotheses, which are based on the constructed conceptual model and the reviewed literature. Therefore, the hypotheses are;

2.7.1 Teacher Quality

To offer a more complete understanding of the linkages between "STEM self-efficacy", PD, and the described requirement for specialized growth, this research examined specific elements of self-efficacy in “early childhood” preservice educators. Participants were preservice educators, either undergrad or graduate, who were selected from the “early childhood program” of a Taiwanese university. Data were gathered for the study using tools such the Need for PD Scale, "Teacher STEM Pedagogical Belief Scale", and “Teacher STEM Self-efficacy Scale”. The survey was completed by 150 preservice preschool teachers in total. Two methods were used to analyze the data: MANOVA and modeling of the structural equations. The findings showed a strong correlation between preservice teachers' self-reported desire for professional development and their scores on the 3 components of STEM self-efficacy and their views about STEM pedagogy. Moreover, via STEM pedagogical beliefs, emotional “attitude predicted teachers' desire for professional development either directly or indirectly”. Furthermore, the outcome showed that the relationship between the two aspects of self-efficacy and the self-reported desire for professional development was mediated by STEM pedagogical ideology

H1: Improvements in students' performance STEM discipline are correlated with high level of instruction credentials and experience.

H2: The efficiency of educator in providing STEM education that is integrated which demonstrated to be greater when they engage in continuous professional development programs.

2.7.2 Professional Development

The determination of this chapter is to add to the body of information on web-based instruction throughout and after COVID-19. The goal of this chapter is to provide the key relevant aspects about the challenges associated with managing the workforce, particularly when it comes to academics who work for colleges or universities. The chapter talks vaguely about their struggles with superiors' ongoing scrutiny, as if they don't know how to provide a lesson with evidence. Faculty unhappiness with this problem has a negative, disparaging impact on teaching qualitative learning performance. This article goes into great detail into strategies that might provide a cooperative solution for efficient staff management both during and after COVID-19.

H3: Teachers gain more self- assurance and competent in their ability to give integrated STEM instruction when they participate in professional development programs that are specifically designed for them.

H 4: There is a favourable correlation between the quality and relevance of professional development training and the level of student engagement and performance in STEM disciplines.

2.7.3 School Infrastructure and Equipment

This study developed an academic warning system by using the strength of large-scale education sector data sources and the latest machine learning methods. Their method is based on academic achievement, which accurately represents a student's standing on academic probation at the institution. They built and retrieved a dataset from raw data sources throughout the study process, which included a plethora of data regarding topics, scores, and students. By using feature creation methods and feature selection procedures, they create a dataset with several characteristics that are very helpful in forecasting “students' academic warning status”. Surprisingly, the dataset they submitted is scalable and adaptable since they provide comprehensive calculation methods whose components may be found at every Vietnamese institution or college. This enables every institution to rebuild or reuse a different dataset that is comparable using its own academic information. Additionally, they used a variety of data combinations, imbalanced data management strategies, model selection tactics, and research to suggest appropriate ML algorithms for the construction of the best possible warning system.

H5: The level of student accomplishment in STEM courses are grater in school that have stronger infrastructure and more sophisticated STEM teaching equipment.

H6: There is a correlation between improved school administration techniques and increased efficiency of STEM education initiatives.

2.7.4 Technology Integration

In order to research the processes of “teachers' roles and teachers' perceived support” from an education communal to overwhelmed hurdles to “AR-integrated STEM” education, this research employed a “social network analysis and a content analysis” to uncover 52 teachers' opinions. The results showed that instructors may experience higher-order funding for incapacitating the relevant challenges to “AR-integrated STEM education” when they hold more influential and key positions in the community of teachers who use AR to teach STEM subjects. Additionally, by highlighting the hidden function and real support—which were seldom highlighted in other studies—this research created a scheme for advancing TPD in AR-integrated STEM instruction.

H7: Improve students learning outcomes and involvement could be achieved through the use of cutting-edge method into the STEM education system.

H8: Through the uses of multimedia and interactive technologies in STEM education, students are able to better comprehend and remember the topics that are being taught.

2.7.5 Student Engagement

This study introduces a new research variable that is classified as extrinsic variables, or internet connectivity and ICT infrastructure, which have an indirect impact on students' inclinations to learn online. This generation uses their smartphones more than previous ones, thus it makes sense to include mobile technology into online education. One method to do this is by using QR codes (Quick Response) in the educational materials.

H9: The correlation between higher level of student participant in STEM activities and greater academic success.

H10: Enhancing students' enthusiasm and engagement in STEM education is crucial by incorporating real-world problem-solving activities into STEM instruction.

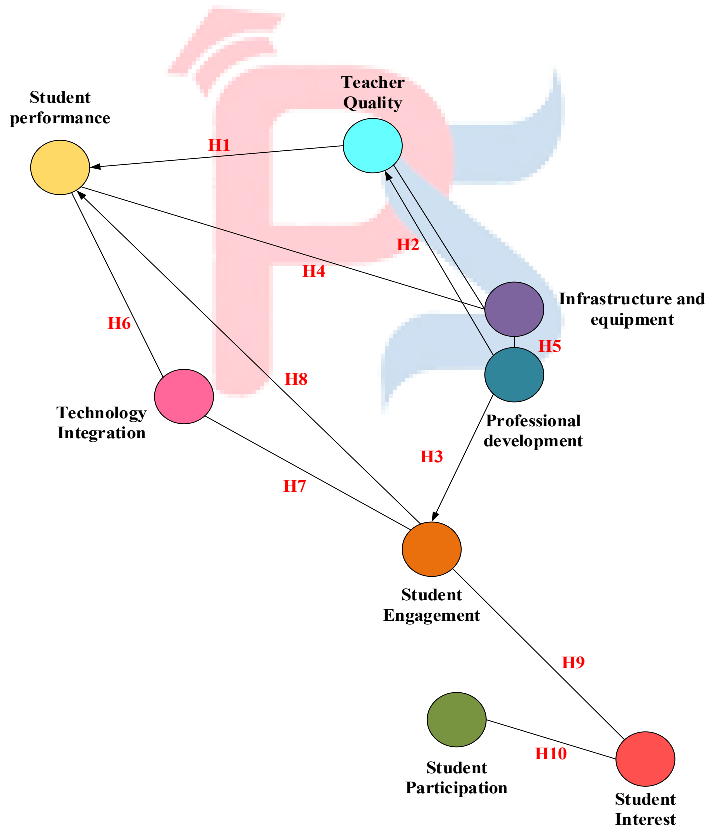

Fig. 2.1 Architecture of related hypotheses

Chapter 3

Research Methodology

3.1 Objective of Integrative STEM Education in Vietnamese high school

Integrative STEM education in Vietnamese high schools aims to achieve a number of important goals. The research first takes advantage of the "VNHSGE: Vietnamese High School Graduation Examination Dataset for Large Language Models" in order to get a thorough understanding of the academic performance of high school students. To improve data comparability and analytical quality, pre-processing entails normalization, which standardizes data across different aspects. The Differential Evolution Algorithm (DEA) is used to help choose relevant variables that are important for forecasting academic success and student pass rates. Additionally, in order to greatly improve accuracy, a hybrid TF-ANN technique is designed to forecast student performance, combining DEA for feature selection. Through the identification of issues with online instruction, Teacher Needs Analysis (TNA) directs the creation of focused training programs that are assessed using Kirkpatrick's four-level Training Evaluation Model. Improving online learning requires using MNI-ML to provide individualized, interactive instruction, which promotes a better understanding of STEM subjects. A Quality Assurance (QA) framework specifically designed for STEM subjects also prioritizes active learning strategies and virtual courses that are outcome-based. When monitoring student performance, fuzzy logic is used to provide insightful information for prompt interventions and advancements.

3.2 Proposed method

The primary aim is to identify the aspects that influence the effectiveness of integrative STEM education in Vietnamese high schools. Overall architecture of the proposed method is illustrated in Fig. 3.1. The key aspects of the proposed method are,

- Data collection & pre-processing
- Feature selection
- Targeted teacher training
- Enhanced online experiences
  - Student education
  - Quality content
  - Monitoring

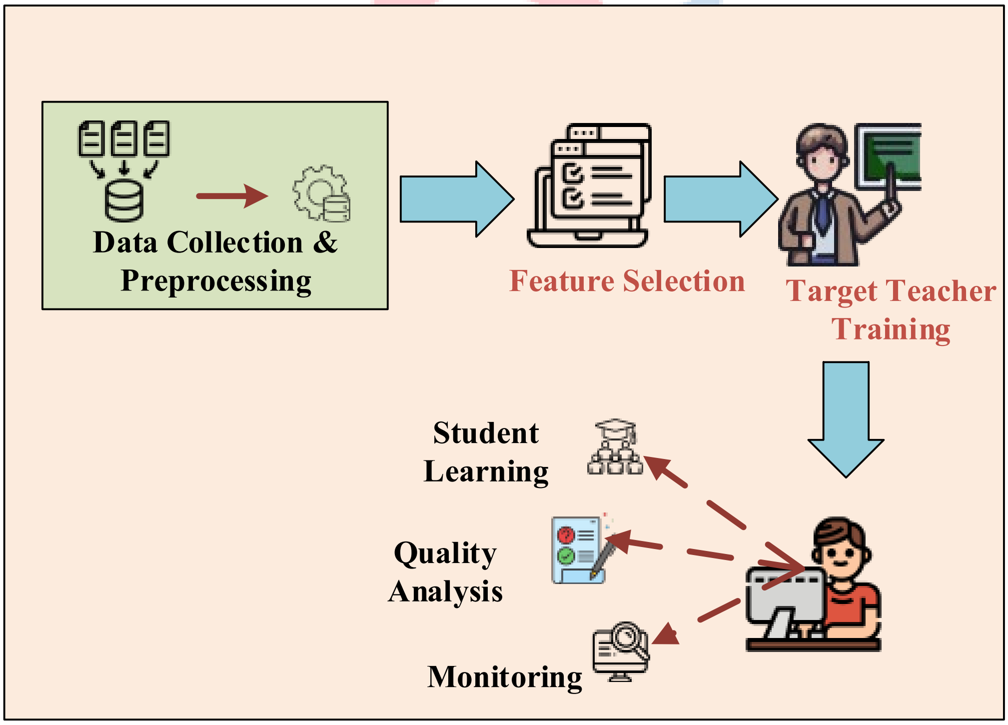

Fig.3.1 Overall architecture of proposed work

3.2.1 Data collection & pre-processing

Initially, we utilized the data from "VNHSGE: Vietnamese High School Graduation Examination Dataset for Large Language Models". This datasets gives a comprehensive insight into high school student academic performance. It provide a depth information on the result of national high school graduation tests, to covering a broad range of topics and including a wide variety of students performance is also measured. Through the investigation of this information, we are able to get significant insights regrading academic trends, strengths, and weaknesses across a variety of courses, and overall student achievements.

3.2.2 Feature extraction

Following pre-processing, we selected the most relevant features using the differential evaluation algorithm (DEA). This algorithm enhances the feature selection by evaluating the contribution of each feature to the prediction of student pass rates. We then applied a hybrid approach that combines the "Random Forest and Artificial Neutral Network (RF-ANN)" to predict academic performance. The DEA is used to select the optimal features then the outputs of selected features were given to the prediction model RF-ANN that predicts the student performance and teachers. The RF-ANN with DEA enhances the accuracy and effectiveness of performance prediction.

3.2.2.1 Differential evolution algorithm (DEA)

Feature selection selects the important characteristics that provide a significant contribution to the model's training in order to enhance the model's functional efficacy, comprehension, and universality while lowering the complexity of the features. In order to assess the significance of learners' learning behaviors, this study employs a differential evolution method, which produces an improved set of characteristics over variance filtering and other filtered selection methods. Initially, feature selection is carried out using the differential evolution process, which is initialized to produce a population of size $\mathcal{N}$. Eq (3.1) illustrates the D-dimensional vector that each unique A_i is made up of. $\mathfrak{D}$ stands for the number of acquired behaviors that each learner produces.

$$A_i = (a_{i1}, a_{12}, a_{i3}, \dots, a_{in}), i \in [1, \mathcal{N}] \tag{3.1}$$

The floats number, ranging from 0 to 1, represents the probability of selecting this option, is associated with each component $A_{ij}, (j \in [1, \mathfrak{D}])$. The feature related to the current component is picked when this value exceeds the threshold value. Eq (3.2), which shows the upper and lower limits of the solution as $\mathfrak{U}_{\max}$ and $\mathcal{L}_{\min}$, assigns values to each component A_{ij}.

$$A_{ij} = \mathcal{L}_{\min} + rand(0,1) \times (\mathfrak{U}_{\max} - \mathcal{L}_{\min}) \tag{3.2}$$

The characteristics that most influence the model's performance is chosen based on the solution fitness value calculation. Because of this, a machine learning model's efficiency value is determined by summing the weighted F1 score, accuracy, and additional measures. To reduce data complexity and improve efficiency, the fitness value computation incorporates the total amount of learning behaviors used. Eq (3.3) illustrates the technique for the $\mathcal{W}th$ mutation after crossover and mutation have been carried out.

$$\mathfrak{M}_i(\mathcal{W}) = A_{p_1}(\mathcal{W}) + S_F \times \left(A_{p_2}(\mathcal{W}) - A_{p_3}(\mathcal{W})\right) \tag{3.3}$$

Here the difference vector is represented by $A_{p_2}(\mathcal{W}) - A_{p_3}(\mathcal{W})$ and the three random solutions in the population are $A_{p_1}(\mathcal{W}), A_{p_2}(\mathcal{W}), A_{p_3}(\mathcal{W})$. Furthermore the S_F is illustrated by the scaling factor. This is the $\mathcal{W}th$ crossover approach.

$$\mathfrak{U}_{i,j} = \begin{cases} cross\left(A_{ij}(\mathcal{W})\right), \mathfrak{M}_{ij}(\mathcal{W}), & rand(0,1) < C_s \\ a_{ij}(\mathcal{W}), & else \end{cases} \tag{3.4}$$

$\mathfrak{M}_{ij}(\mathcal{W})$ and $A_{ij}(\mathcal{W})$ produce new individuals $\mathfrak{U}_{ij}$. Let's say there are less randomly produced people than the crossover (C_s) rate cutoff. The j^{th} component of the i^{th} individual of the $\mathcal{W}^{th}$ crossover should then be crossed with the component of the matching variant person. Utilizing the adaptive crossover rate with Eq (3.5), we can stop the early population from "early maturing" and preserve the stability of the later population.

$$\Lambda = e^{(1-\mathbb{T}/(\mathbb{T}+1-\mathcal{W}))} \tag{3.5}$$

where $\mathcal{W}$ represents the current iteration count and $\mathbb{T}$ represents the total number of iterations. Lastly, compute the fitness of the new population. The selection formula for each member of the population is given by Eq (3.6).

$$A_i(\mathcal{W}+1) = \begin{cases} \mathfrak{M}_i(\mathcal{W}), & \mathcal{F}(\mathfrak{M}_i(\mathcal{W})) > \mathcal{F}(A_i(\mathcal{W})) \\ A_i(\mathcal{W}), & else \end{cases} \quad (3.6)$$

where the fitness function is represented by $\mathcal{F}$; the procedure is stopped after a number of iterations or upon reaching the condition. It is determined which set of solutions is best for feature selection. Subsequently, the input for feature fusion is the current optimum collection of feature solutions.

3.2.2.2 Artificial neural network

It is possible to predict students' academic achievement using discriminative neural networks. A basic artificial neural network serves as the study's first prediction model. Eq (3.7) shows the mathematical representation of neural networks as a function.

$$\mathcal{O}^* = \mathcal{F}_p(\mathcal{I}) \quad (3.7)$$

In other words, the prediction output $\mathcal{O}^*$ is calculated by a neural network from an input $\mathcal{I}$ by utilizing the defined function$\mathcal{F}_p$. This function, denoted$\mathcal{F}_p$, is made up of a series of phases joined together by a non-linear function. Every step has p parameters, which are the deep learning language's weights and are used for addition and multiplication. Fig. 3.2 illustrates the operation of an artificial neural network using a toy example. Initially, the values of the student characteristics are arranged as an input vector$\mathcal{O}u$. Next, before going on to the neurons, a linear operation (a dot product) is carried out using the input vector $\mathcal{O}$ and the parametersp^1. The weighted sum of $\mathcal{O}$ and p^1 that result is sent by the neurons to a non-linear function, such the Rectified Linear Unit (ReLU). ReLU, in short, returns the weighted sum as shown in Eq (3.8) and puts any negative weighted sum to zero.

$$\mathcal{R}(\mathcal{I}) = \max(0, \mathcal{I}) \quad (3.8)$$

With distinct parameters p^2, the same linear procedure is carried out between the first layer's output values (h). This time, the weighted sum will be sent by the second layer neuron to a sigmoid ($\mathcal{S}_d$) function Eq (3.9), which will compress the result to a value in the range of 0 to 1.

$$\mathcal{S}_d(\mathcal{I}) = \frac{1}{1+e^{-\mathcal{I}}} \quad (3.9)$$

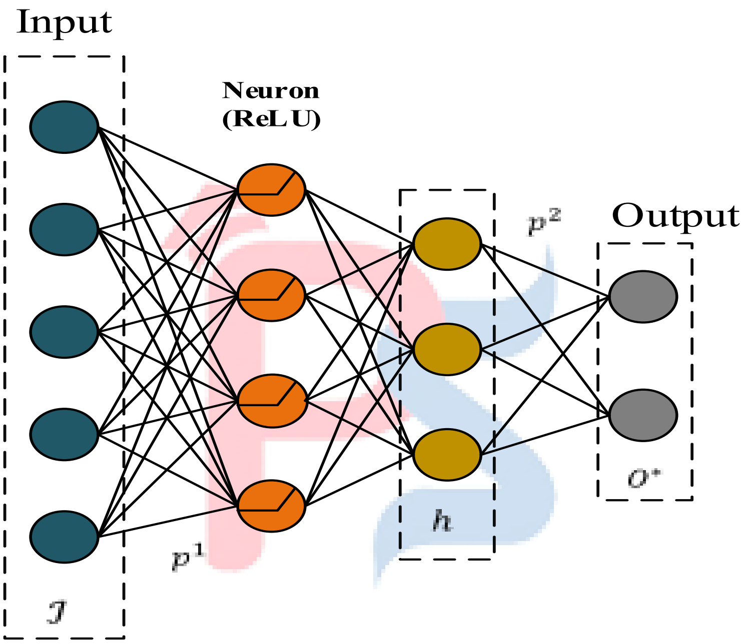

Fig. 3.2 Two layer Artificial Neural Network

The process of training a neural network involves selecting the parameter values that provide the best prediction results. A function that measures the error difference between the actual student's outcome$\mathcal{O}$, and the anticipated result$\mathcal{O}^*$, is created in order to do that.

$$loss = -(\mathcal{O}.\log\mathcal{O}^* + (1-\mathcal{O}).\log(1-\mathcal{O}^*)) \quad (3.10)$$

An optimization approach is used to minimize the loss function by varying the valuesof parameters p in order to determine an ideal set for the parameters p. The most widely used optimization techniques are gradient descent methods. Random forest is another predication method. This model combines decision tree algorithms with the bagging predictors approach first presented by. The random forest algorithm's operation for predicting students' academic achievement is described. The following stages provide a summary of the algorithm:

3.2.3 Targeted teacher training

Effective teacher training is the crucial for enhancing the quality of online teaching. We conducted a **training needs analysis (TNA)** to identify the issues that is faced by primary and secondary school teachers in online teaching. Based on TNA output we designed **need-based-training program** to overcome the issues. To create an efficient training program that would reduce the amount of online instruction needed to bridge the skill and knowledge gaps between the instructors' present and optimal levels, a training needs analysis (TNA) was conducted.

3.2.3.1 Training effectiveness evaluation

In this research, the Kirkpatrick Four-Level Training Evaluation Model was used to gauge how successful the teacher training program performed. Reaction, learning, behavior, and outcomes are the four stages. We can ascertain the success of the training program by examining each stage.

Level 1: The Response of the Teachers to the Training Course. Reaction analysis after training is a well-known method of assessing training effectiveness. Consequently, each participant was given a questionnaire consisting of four questions to gauge their response to the training session.

Level 2: This level's objective is to ascertain if the participants have gained the necessary attitude, abilities, and information from the training course. Therefore, just after the training session, a six-question evaluation was carried out. The questions were separated into two categories:

- Strategies for running online classrooms utilizing digital platforms and
- Online class activities and demonstrations. The questions were created based on the training program's primary learning goals.

Level 3: After participating in the training program, teachers exhibited different behaviours. This level-3 was designed to find out if the learners' behavior was affected by the training program. To measure teachers' behavioural changes, systematic online classroom observations were conducted.

Level 4: After the training program, the confidence and satisfaction of teachers with online instruction. The purpose of this level-4 study was to determine how the training program really affected the pleasure and perceived confidence of instructors while they were teaching online. Kirkpatrick based four level training architecture is presented in Fig. 3.3

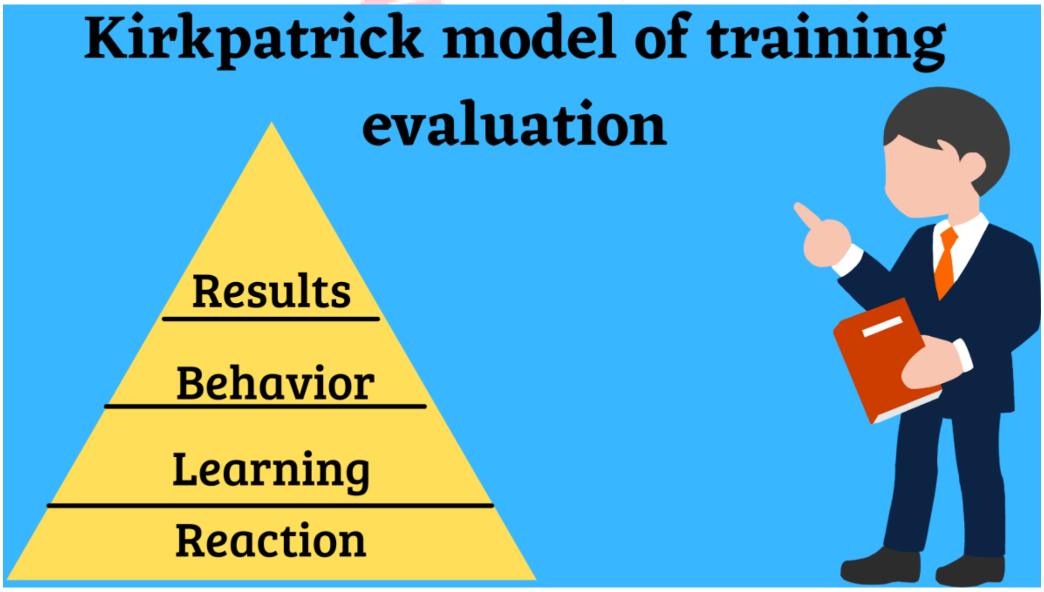

Fig. 3.3 Kirkpatrick Four-Level Training

3.2 Fix-and-Optimize Heuristic combined with a variable neighborhood descent strategy

Furthermore, we implement the "Fix-and-optimize heuristic combined with a variable neighborhood descent method (FOH-VDM)" to enhance the high school timetabling. This method utilizes decompositions at the class, teachers and the day by day facility efficient scheduling. In light of the fact that other choice variables are dependent on the set of variables v, this set is the most essential of the bunch. This indicates that if this set is dependent upon the values of v variables. This implies that it is simple to determine the values of the other variables if the values of v are fixed. This feature suggests that the fix-and-optimize heuristic would be able to solve the issue since there would only be two options if binary variables were fixed to integer values. In the fix-and-optimize heuristic, the number and selection of variables to be fixed have a direct bearing on the algorithm's performance as well as the final solution's quality, or the degree to which the soft constraints are satisfied. Decomposition operations must thus differ in kind and scale.

- "Class decomposition" (CD): It's possible to optimize a certain number of classes.

- "Teacher decomposition" (TD): A certain number of educators are available for optimization.
- "Day decomposition" (DD): There is a certain number of days available for optimization.

It is crucial to understand that when a lesson, teacher, or day is accessible for optimization, it means that none of the factors related to the happenings of that school environment, teacher, or day are predetermined.

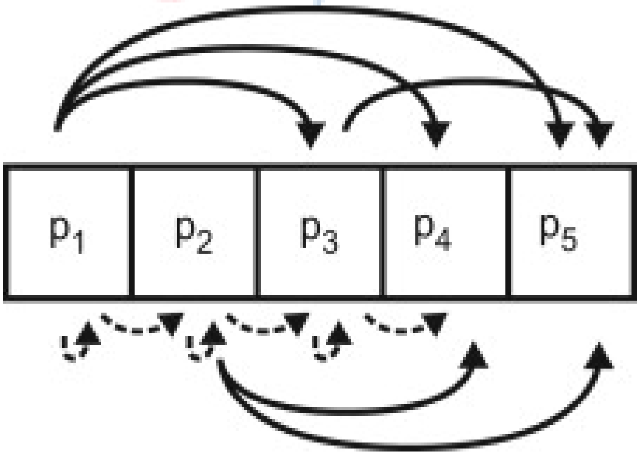

Fig. 3.4 Idle period graph

The dimension of the collection of parameters that are available for optimization can be determined by a parameter k for each form of decomposition τ. Taking into account the decomposition CD. The "fix-and-optimize heuristic" action on a toy case of the issue is shown in Fig. 3.4.The system consists of three classes (CL_1, CL_2, CL_3), six teachers, four periods $(\mathbb{P}_1, \mathbb{P}_2, \mathbb{P}_3, \mathbb{P}_4)$, and just for a single day. The method begins with an achievable resolution and, at each iteration, resolves a separate sub issue. It's important to note that the process starts with the neighborhood $(\mathcal{C}, 1)$ and makes two improvements to the current solution. By the sixth iteration, the neighborhood receives a change to $(\mathcal{C}, 2)$, resulting in the algorithm's ability to further enhance the solution. The example of allocation circumstances is shown in Fig. 3.5.

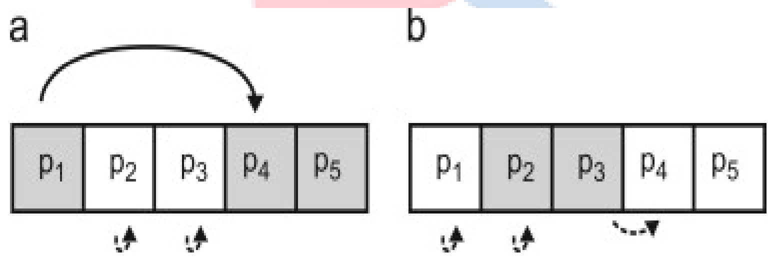

Fig. 3.5 Example of allocation circumstances

Algorithm: 1 Fix-and-Optimize

Create starting solution $\rightarrow S^*$
if $S^* = \emptyset$ **then**
    return $\emptyset$;
end if
for all $(\tau, k) \in \mathcal{N}$ do
    count $\leftarrow$ sub problem count (τ, k):
    $u \leftarrow 1$;

8. $0 \rightarrow no\ improve$
9. **repeat**
10. Decompose $(\tau, k, u) \rightarrow \mathfrak{D}$
11. $S \leftarrow$ solve $(S^*, \mathfrak{D}, STL)$;
12. **if** S is better than S^* **then**
13. $S^* \leftarrow S$;
14. $0 \rightarrow no\ improve$
15. **else**
16. $0 \rightarrow no\ improve$
17. **end if**
18. **if** TL was reached then
19. **return** S^*
20. **end if**
21. $u \leftarrow (u\ mod\ count) + 1$;
22. **unit** no improve = count;
23. **end for**
24. **return** S^*

The algorithm 1 shows how the whole method works. The outer loop goes through a list of neighborhood structures $\mathcal{N}$. Function count figures out how many

sub problems there are in each neighborhood. Sub problems as shown in the pseudocode in algorithm 2. u Stands for the quantity of smaller issues. The amount of τ is determined by the kind of breakdown and its size$k$.

As shown in lines 9–22 of the inner loop, the sub problems of the current neighborhood are looked into until $no\ improve$ is reached. This means that the algorithm evaluates each subproblem (within the subproblem time limits of the neighborhood (τ, k)) and tries to make the current solution better by increasing the level of satisfying the soft constraints.

Algorithm 2: Sub problem count (τ, k)

Switch (τ)
Case CD
Count $\leftarrow \binom{|C|}{k}$;
Case TD

```
            Count ← (|T| choose k);
      Case DD
            Count ← (|D| choose k);
end switch
Return count.
```

$$\text{Count} \leftarrow \binom{|T|}{k}; \quad \text{Count} \leftarrow \binom{|D|}{k};$$

The function disassemble is utilized to find the number of variable that need to be improved ($\mathfrak{D}$) in this issue, based on the pseudo-code shown in algorithm 2. When you call the function$subset\ (c, k, u)$, it will return the u^{th} subset of all the parts of u that have exactly k elements. Next, the function solution is used to solve the sub problem. It requires the following arguments: the present answer (S^*), the factors requiring enhancement ($\mathfrak{D}$), and the subproblem's time boundary.

3.2.4 Enhanced online experience

3.2.4.1 Student education

We employ the "**multimedia network interpretation teaching using machine learning (MNIT-ML)"** to improve the traditional teaching approaches. MNIT-ML combines the multimedia resources with ML algorithms to generate the personalized and interactive learning experiences for students.

3.2.4.1.1 Communication through a multimedia medium

A model that employs multimedia technology to provide or transmit information to participants is the standard for instructing successful communication. In the teacher sends pre-tech information. The learner receives relevant facts from the instructional content such as knowledge or statements. Every instructor has the option to use either blackboards or transparencies as the means of delivering their presentations. Curricula refer to well designed and organized sets of courses, instruction, and educational experiences that students are expected to complete. Instruction entails instructors using strategies to augment student understanding and proficiency advancement. Inspections, quizzes, and work by pupils are all forms of evaluation. The "learning environment," or physical and social backdrop for education, includes the classroom, school, and community.

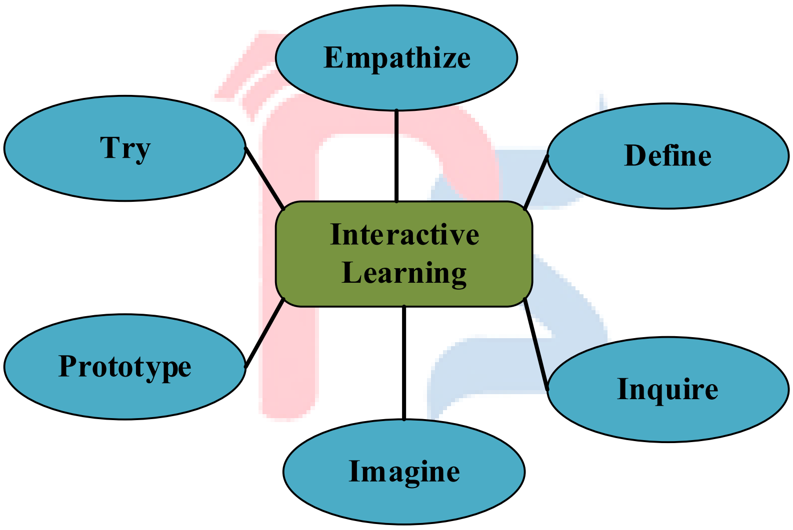

Fig. 3.6 Relationship of an interactive process

In pre-tech education, as shown in Fig. 3.6, the teacher is the one who sends or gets the tools. The phrase "resources" mentions to equipment, resources, and methodology utilized to enhance classroom learning. Some mechanisms, like program planning and assessment examination of data, can be employ mathematical formulae, but mathematics is not the main emphasis of education. Education is a complex process that involves many of the above factors. The instructor manages educational procedures, offers class material, and shows factual facts. Stated differently, the curriculum facilitates both student acquiring knowledge and lecture content. The learning method is forceful, with little student accountability.

$$w_{\mathfrak{d}}(i) = \frac{\ln le+1}{\sum_{X=1}^{x}(\ln X+1)} * \frac{X^2}{x} \tag{3.11}$$

$$w_{\mathfrak{d}} = \frac{\ln le+1}{\sum_{X=1}^{x}(\ln X+1)} * \iint w_{\mathfrak{d}}(i) \tag{3.12}$$

By applying eq (3.11) to the instruction manage; the multimedia model transforms it into a variable-length matrix. In the X^{th} lesson in the evolution $(X < x)$, the first rows contain information, while the last row is empty. Thus, missing data must be filled to maintain the matrix structure using the summing procedure with limitations$X = 1\ to\ x$. Reviewing learning integral features using $w_{\mathfrak{d}}(i)$ weight computation from eq (3.12), available data is filled with a weighted average depending on the current condition. Let X be the lesson

number and $w_{\mathfrak{d}}$ be the weight dynamic. Virtual material is versatile and could be used in many instructional and learning contexts.

The "flipped classroom" is a teaching method where lectures are provided online. Students subsequently debate, interact, or solve problems in-person. By using technological tools like online classes and readings, educators may ensure that students come to class well-prepared and can focus on completing relevant assignments and activities during class time.

Providing students with online course materials before class is called "reverse instruction" and allows them to examine the content on their own time before class. Instructors lead students in engaging discussions and activities that reinforce previously studied content. This kind of education could develop a deeper and more enduring relationship to the subject matter. Virtual content facilitates successful teaching and learning by engaging students, fostering analytical thinking, and fostering group projects.

3.2.4.1.2 Multimedia based enhanced teaching

Multimedia provides benefits over conventional schooling. Students have the flexibility to study at their own speed by exploring and learning at different levels. In Fig. 3.7, teaching and learning methods are illustrated. While the presentation differs, learners may foster bidirectional contact between users and computers. This learning style prioritizes student-cantered, self-directed learning to meet individual needs, in contrast to mass learning through guided teaching. The "interactive model" refers to multimedia training that involves real-time interaction with text, images, audio, and video to engage students in the learning process. In this concept, students actively interact with information rather than just receiving it. Integrating multimedia into instruction is crucial for the interactive approach. The word "multimedia" refers to the combination of several media kinds, including text, pictures, sounds, and videos, into an instructional tool. A flexible transmission medium is used in improved multimedia teaching to meet the demands of each classroom. Enhanced multimedia education uses various transmission means for instance, multimedia CDs, digital whiteboards, smartphone apps, and online instruction environments.

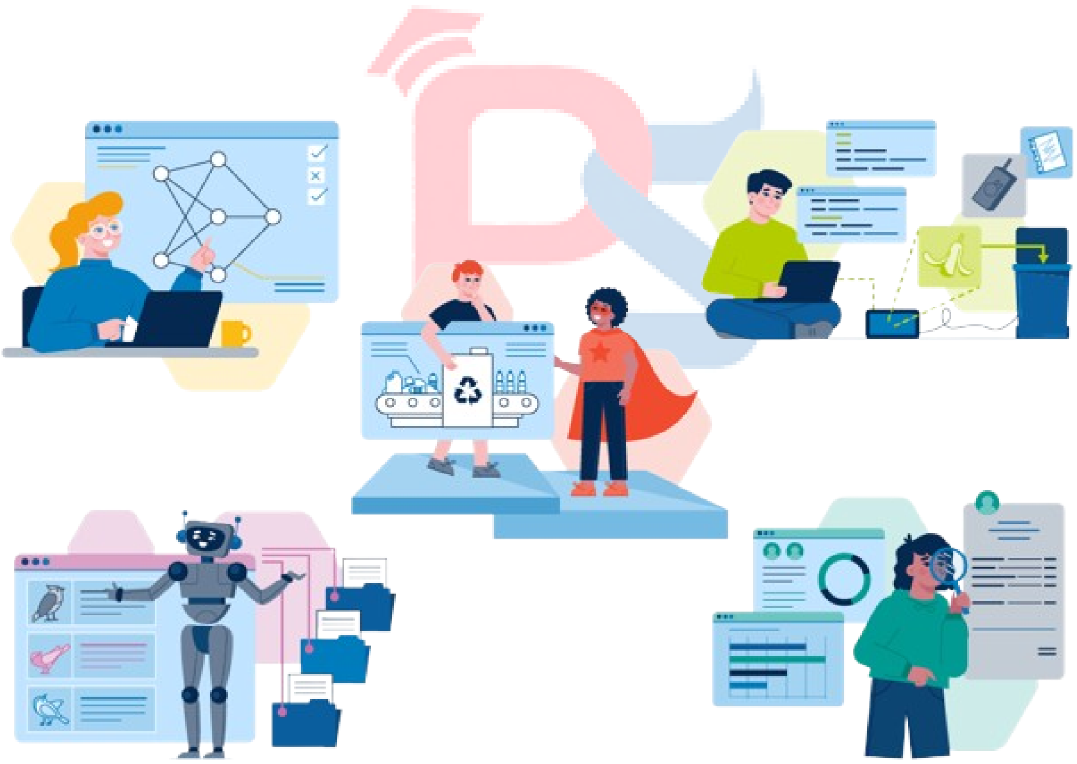

Fig. 3.7 Architecture for multimedia teaching

Improved multimedia education seeks to promote active learning and engagement by providing interactive tools and experiences. New teaching methods and strategies have been created employing digital multimedia technology. It fosters innovative learning patterns and innovative teaching methods for pupils. The educational atmosphere is more IT-focused.

$$Students_p = (lef)(1 - op) * \sqrt{G(tp)G(tp)} \qquad (3.13)$$

The eq (3.13) calculates user satisfaction$Students_p$, with the training error for students as $Students_p(lef)$, the acquired possibility as $(1 - op)$, and the expected benefit as $(tp), (tp)$. The squared root quantity G could be assessed using functional formulae to evaluate instructional efficacy.

$$E_{ob}(\mathcal{P}_n, \mathfrak{S}_n) = \begin{cases} \frac{1}{2} * r_m \, if \left(\left| \int \mathfrak{S}_{n,i} - \mathcal{P}_{n,i} \right| i, & E_{ob} \le 1 \\ 0, & otherwise \end{cases} \qquad (3.14)$$

Eq (3.14) represents the decrease in mistakes in the interaction among teachers and students, specifically at the stage denoted as r_m. Error observing E_{ob} data often indicates student numbers $\mathfrak{S}_n$ and partitions $\mathcal{P}_n$, with constant values i for movement recognition in multimedia education methods.

$$mes\ (\mathfrak{S}_n) = \begin{cases} 1, \sqrt{r_m^2 - \mathfrak{S}_n^2} * as, & \mathfrak{S}_n \ge 1 \\ r_m \ge 0, & otherwise \end{cases} \qquad (3.15)$$

To estimate mes using the teaching approach, utilize eq (3.15), where $\mathfrak{S}_n$ is the squared root number of symbols used. as represents cumulative sentences in teaching to attain the topic. Because they may access top-notch resources and get instruction from any location with a connection to the web, students benefit greatly from online education. Students are provided with the chance to engage in active and interactive instruction, which enhances their critical thinking and solving problems abilities. Greater availability to learning assets and possibilities via digital learning may help students develop skills relevant to their future careers.

$$acc_{pt} = \frac{1}{F_n} \sum_{i=1}^{q} T_{lq,i}(R) \tag{3.16}$$

The portion of instruction that accumulates Eq (3.16) yields acc_{pt}, which indicates the total quantity of points in the teaching-learning process. T_{lp} that F_n is a typical feature and $T_{lq,i}$ uses a summation procedure with constraints $i = 1\ to\ p$ to illustrate the rate of a single interaction R.

$$Teacher_{pro} = \sum_{\mathcal{Z}=0}^{n} \sqrt{\mathcal{B}_{\mathcal{Z}} * n_{\mathcal{Z}}} \tag{3.17}$$

The eq (3.17) is used to calculate the whole teaching process ($Teacher_{pro}$), where $\mathcal{B}_{\mathcal{Z}}$ stands for the conventional teaching native code and $n_{\mathcal{Z}}$ for the new screening procedure. $\mathcal{Z}$ stands for several system learning components. It is reversed and not instructional material if the squared root value exceeds the threshold $\mathcal{Z} = 0$. The Web, email, discussion boards, and file transfers are the inventors of e-learning platforms, virtual universities, and continuing education facilities.

3.2.4.1.3 Multimedia technology in learning resource

Teachers may choose appropriate course materials based on the real learning objectives of each assignment by using a variety of multimedia learning activities. The constraints of centralized or corrected teaching techniques could be overcome by students with diverse learning areas and educational materials thanks to multimedia technologies. The learning process to their own needs the "Adaptive Learning Resources (ALR)" framework attempts to optimize students' use of available resources by tailoring. To examine a student's learning preferences and behaviors, and then adjusts the learning materials provided based on these discoveries in order to do this, it employs machine learning and data analytics methodologies. By using the ALR structure, learners may avail themselves of cutting-edge learning resources such as multimedia content, modeling, and customized evaluation. These materials are tailored to the learner's learning style, passions, and skill level to encourage learning through active participation, and knowledge retention. Figure 3.9 depicts the precise arrangement of the multimodal sound-visual materials that are accessible at the university library. These resources have the ability to modify the learning environment and boost educational effectiveness.

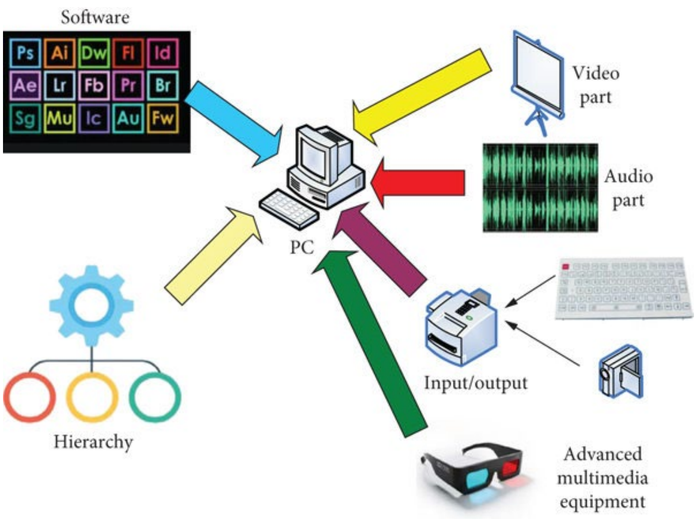

Fig. 3.8 Teaching process with multimedia resources

3.2.4.2 Quality content

The development of a **quality assurance (QA) framework** was done with the intention of enhancing the delivery of high-quality course material. This framework is tailored to STEM subjects and emphasizes virtual courses with active learning strategies and outcome-based learning. Three interacting stakeholders form the basis of a quality assurance system for course design and delivery. A collection of activities that comprise design, delivery, training, support, and/or evaluation is referred to as a constituent. As a result, although it is a choice, constituents are not required to contact with specific departments, offices, or divisions within institutions. The QA framework consists of the following three components (Fig. 3.9):

- A component of the institution known as "Information and Communication Technology Support" (ICTS) is responsible for overseeing the Learning Management System (LMS) and offering assistance to educators in the planning and execution of course design.
- One of the components of an educational institution known as "Teaching and Learning Support" (TLS) that provides instruction in active learning approaches

and outcome-based teaching. instruction of teachers and students in the LMS's learning capabilities inside the institution. Furthermore, TLS provides training to educators on how to effectively communicate in a virtual environment.

- A "Course Management System" (CMS) component serves as a roadmap for teachers' successive actions during the creation, delivery, and direct evaluation of outcome-based, online, live classes that integrate active learning techniques. It also offers a mechanism for teachers' performance to be evaluated indirectly.

Collaboration between the three stakeholders must be founded on defined procedures for the creation and delivery of courses in an efficient manner. Each of the three components' policies and processes, together with the corresponding quality assurance standards and requirements, would be developed under the direction of the QA framework.

Fig. 3.9 Quality assurance (QA) framework

A QA framework guarantees the effectiveness of the present teaching cycle and, ideally, creates protocols for ongoing program and teaching practice development. By adhering to this paradigm, instructors may create and deliver online courses that are both interesting and productive.

3.2.4.3 Monitoring

To monitor the students' academic performance is essential for identifying the areas of improvement. So, we utilized the **fuzzy logic**, a form of AI to monitor the student performance. By analyzing the numerous factors such as attendance, participation, and assessment scores, fuzzy logic provides the valuable insights into the student progress and allows for timely interventions. It is possible to define a Fuzzy Logic System (FLS) as the nonlinear mapping of a collection of input data to a set of scalar output values. Rules, a defuzzified, an inference engine, and a fuzzified are the four fundamental components of a FLS (Fig. 3.10).

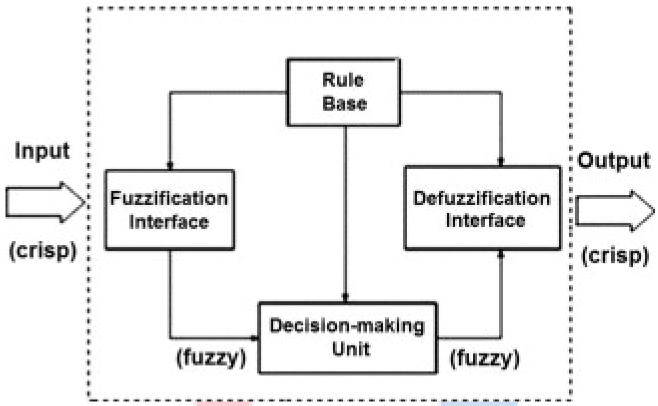

Fig. 3.10 Fuzzy logic based monitoring

Numerical data is mapped into fuzzy sets through the fuzzified. The output sets are mapped into sharp integers by the defuzzified. Finally, we combine **MNIR-ML-QA-FL** to enhance the overall performance of STEM education by optimizing the interactions, content quality and the monitoring process. The MNIR-ML-QA-FL framework leverages the strengths of multiple computational approaches to improve STEM education outcomes. MNIR (Multi-Nominal Interaction Representation) captures and models the complex interactions between teachers, students, and learning resources, enabling personalized and adaptive learning experiences. ML (Machine Learning) algorithms analyze large datasets to identify patterns, predict learning outcomes, and recommend targeted interventions, while QA (Quality Assessment) ensures that educational content, teaching strategies, and student performance meet established standards. Fuzzy Logic (FL) is employed to handle uncertainties and imprecise information in educational environments, such as varying student engagement levels, differing teacher competencies, and inconsistent classroom conditions. By integrating these components, the system can dynamically optimize instructional strategies, improve content delivery, and provide real-time feedback for both educators and learners. The combined MNIR-ML-QA-FL approach enhances decision-making, supports continuous monitoring of STEM education processes, and ultimately contributes to higher learning efficiency, better skill acquisition, and improved overall educational performance.

Chapter 4

Results and Discussions

In this case, we simulate and experimentally evaluate the elements that influence the effectiveness of integrating STEM instruction in Vietnamese high schools. The setup of the simulation, the use-case scenario, the analysis, and the study summary are all included in this section. A simulation will be used to evaluate the proposed system, and a comparison study will be performed to assess how well the system by comparing its performance metrics against those of previously developed works.

4.1 Performance metrics

This section describes the experimental results of the proposed research approach for performance assessment. This part is divided into three subsections: simulation setup, comparative analysis and study summary. For evaluation purpose, four performance metrics are monitored: prediction rate, precision, F1-Score, and recall.

4.2 Simulation setup

Initially, we collect and pre-process the Vietnamese High School Graduation Examination Dataset. Then, we implement the differential evaluation algorithm (DEA) for the feature selection process. Then, we implement random forest and artificial neutral network (RF-ANN) to predict student academic performance. Next, we implement Kirkpatrick's 4 levels Training Evaluation Model to overcome issues in online teaching. Next, we implement

"Multimedia network interpretation teaching using machine learning (MNIT-ML)" to generate personalized and interactive learning experiences for students. Next, we implement a quality assurance (QA) framework personalized to STEM fields for designing and delivering engaging online courses. Next, we implement Utilize fuzzy logic to monitor student performance. Finally, we plot graph for the following metrics: Number of Epochs vs. prediction rate (%), Number of Epochs vs. F1-score (%), Number of Epochs vs. Precision (%), Number of Epochs vs. Recall (%).

The simulation environment and setup for the identification of the factors that influence the efficiency of integrate STEM education system in Vietnam high school. This suggested method is tested in a 2750 × 2250m simulated setting. The setup of the system is shown in table 4.1.

TABLE 4.1

SYSTEM SPECIFICATION

Hardware specifications	Hard disk	300 GB
	RAM	8GB
Software specifications	Simulation tools	Python 3.11.4
	Processor	Intel(R) core™ i5 -4590S CPU@3.00GHZ
	OS	Windows 10 Pro (64-bit)

4.3 Comparative analysis

The comparative analysis of the proposed framework is summarized in this section, where we take into account 4 Scenarios. We compare the metrics for four scenarios including the Number of epochs vs. prediction rate (%), Number of epochs vs. precision (%), Number of epochs vs. F1-Score (%), and Number of epochs vs. Recall (%). Each scenario detailed below,

Scenario 1:

In scenario 1 by manipulating the number of epochs and evaluating the model performance on an evaluation set after each training phase, we track the temporal fluctuations in the prediction rate. To analysis the relationship between the total number of epoch and prediction rate. The result of our study findings, expanding the number of epochs often leads to an initial enhancement in the predicted rate. It is crucial to select the most suitable epochs that establish the optimal relationship between the performance and generation, in integrated STEM education system settings to get the high level of prediction accuracy.

Scenario 2:

The relationship between the number of training epochs and precision od model is investigated in scenario 2. Precision metrics are generated for a variety of various epoch configuration to assess the extents of which model was able to effectively furcate the positive instances that were predicted. Our research indicates that as more epochs pass and the model grows stronger at making accurate predictions, its accuracy often increases. However, using an excessive amount of epochs might lead to a trade-off between high accuracy and reduced recall.

Scenario 3:

The F1-score is a metrics that balances the accuracy and recall which is investigated in the scenario 3. To achieve a trade-off between accurately identification of positive case and minimize the occurrence of false positive rate through the computation of F1-score which access the variations in training during on the models capacity. The process of calculating affirmative example we us the ascertain the impact of the model was examined. Our research indicates that the certain specific time periods are optimized for achieving the highest possible F1-Score.

Scenario 4:

To accurately identify all related occurrences related to the problem, the correlation between the number of training epochs and recall, examined in scenario 4. Which help us to understand how sensitivity evolves during training, recall rates are assessed at number of epochs. The outcome our research is indicates that an increase in the number of epochs, which signifies the methods, enhanced capacity that identifies the more positive occurrences which also improve the memory. Through the implementation of STEM education system which optimize the effectiveness of model.

4.3.1 Number of epochs vs. Prediction rate (%)

The correlation among the number of epochs ($\mathfrak{E}$) vs. prediction rate is represent as follows w:

$$P_R(\mathfrak{E}) = x\mathfrak{E}^2 + y\mathfrak{E} + z \quad (4.1)$$

Here, $P_R(\mathfrak{E})$ is the prediction rate as a function of epoch, and (x, y, z) represent the coefficients determined by fitting the curve to the data. The number of epoch vs. prediction rate (%) and the numerical result of prediction rate are shown in figure 4.2. When comparing the Prediction rate of different topologies, it can occur to see significant differences, as shown in Table 4.2.

Table 4.2

Number of Epochs vs. Prediction Rate (%)

Number of epochs	Prediction rate (%)		
	Proposed	MANOVA	ANN
10	85	78	74
20	89	80	77
30	92	83	80
40	95	87	84
50	98	91	87

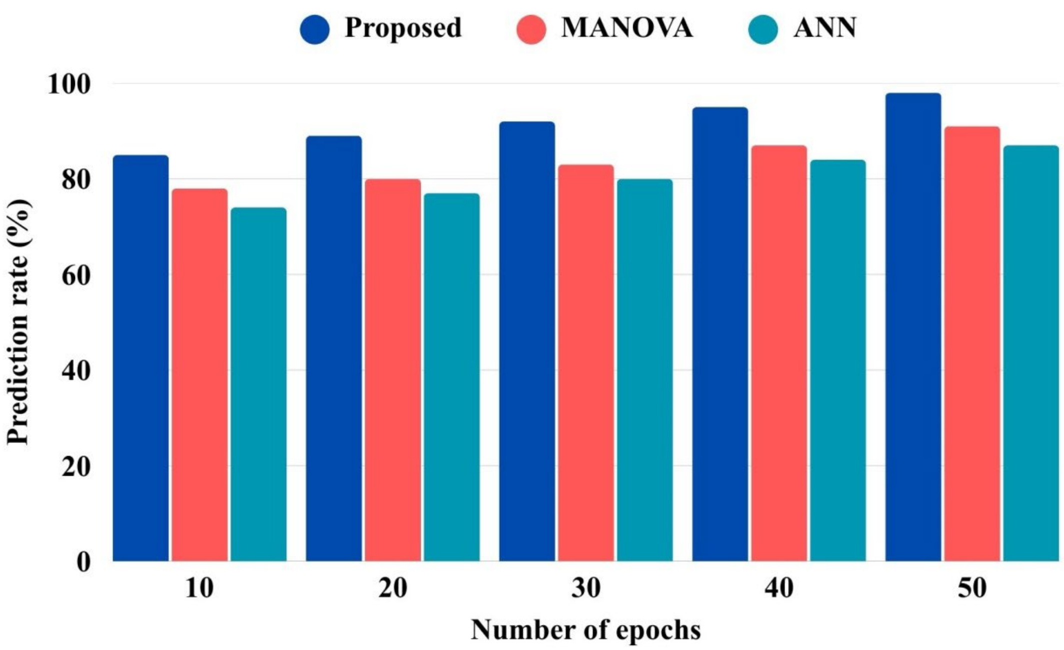

Fig. 4.1 Number of Epochs Vs. Prediction Rate (%)

The table and figure provides a comparative examination of the prediction rate achieved by each of the three different approaches such as MANOVA (Multivariate Analysis of Variance), (ANN) Artificial Neural Network (Ong et al 2022) across various range of epochs. The number of times that the training dataset is traversed in its whole throughout the training phase is referred to as the epoch quantity. At the beginning, after ten epochs, the suggested technique exhibits a significant prediction rate of 85%, which is superior compared to (Chen et al 2021) MANOVA (78%) and ANN (74%). The suggested technique continues to demonstrate better performance even as the number of epochs expands. A prediction rate of 89% is achieved by it after 20 epochs, which is higher than the rates of 80% for MANOVA and 77% for ANN. This pattern of greater accuracy for the suggested technique continues, with 92% accuracy having been achieved at 30 epochs, 95% accuracy having been achieved at 40 epochs, and achieving an amazing 98% accuracy at 50 epochs. On the other hand, while MANOVA and ANN both show signs of improvement with increasing epochs, they continue to fall behind the approach that was introduced. When 50 epochs have passed, MANOVA has reached 91%, whereas ANN has reached 87% at the same point in time. The success of the suggested strategy is shown by the fact that it has a distinct advantage in terms of prediction rates across all epochs. The statistics show that the suggested technique not only learns more effectively than the other ways, but it also reaches greater accuracy more rapidly than the other methods. As a result, it is a more dependable option for jobs that need predictive analysis.

4.3.2 Number of epochs vs. Precision (%)

A function that illustrates how the precision changes with more training could be used to describe the connection between the number of epochs and the precision (%). The precision (%) of students in integrative STEM education has a tendency to improve as the number of epochs develops; nevertheless, there is a possibility that the results could decrease with time. The following is an example of a fundamental scenario:

$$\mathcal{P} = x \times \ln(\mathfrak{E}) + y \tag{4.2}$$

Where, $\mathcal{P}$ represent the precision and a possible logarithmic connection is demonstrated by the expression $\ln(\mathfrak{E})$, which is the natural logarithm of the number of epochs. This relationship indicates that the precision of the model increases less with each subsequent epoch as the training improvements. An examination of the correlation between the number of epoch and the precision provides the outcome presented in Table 4.3 and Fig. 4.2

Table 4.3

Number of epochs vs. Precision (%)

Number of epochs	Precision (%)		
	Proposed	MANOVA	ANN
10	84	73	67
20	87	76	71
30	90	79	74
40	93	82	77
50	95	85	81

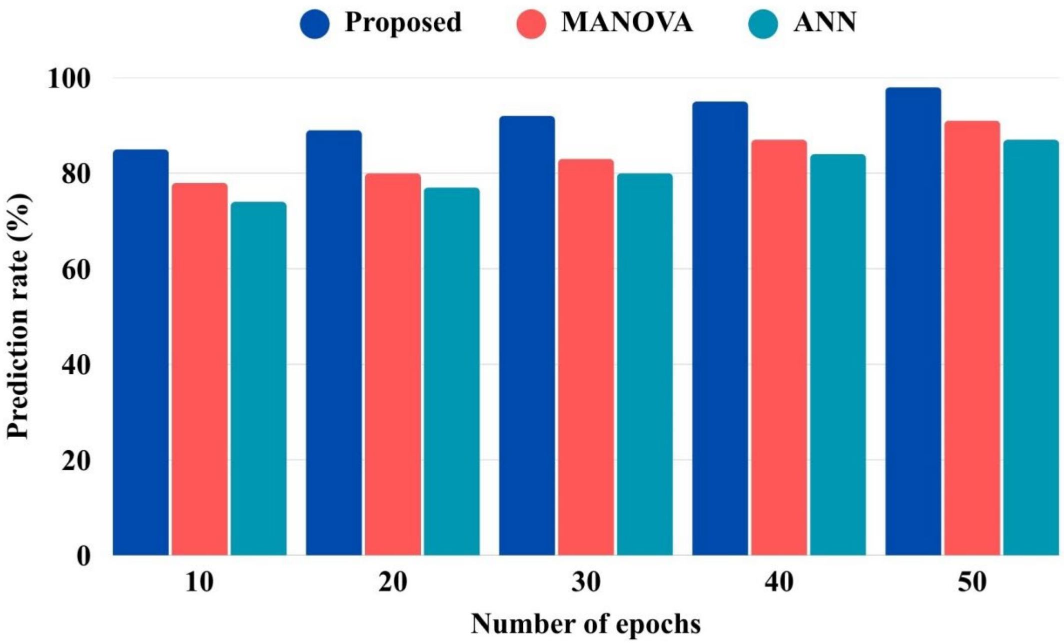

Fig. 4.2 Number of epochs vs. Precision (%)

There are three approaches that are compared in this table: the Proposed method, MANOVA (Multivariate study of Variance), and ANN (Artificial Neural Network). The table shows a comparative study of precision (percentage) across various numbers of epochs. The proposed technique continually outperforms the other two, beginning with a high accuracy of 84% at 10 epochs and slowly growing to 95% at 50 epochs. This is the case throughout the whole process. In comparison, MANOVA starts at 73% and improves to 85% over the same period, while ANN begins at 67% and improves to 81% over the same course of time. These statistics emphasize the better performance of the proposed technique, which not only achieves higher initial accuracy but also displays more efficiency and effectiveness in learning, hence keeping its advantage over all epochs. Moreover, the proposed method maintains its advantage over other methods.

4.3.3 Number of epochs vs. F1-Score (%)

The configuration that is often observed in the connection between the number of epochs and performance measurements such as F1-Score in the context of training machines is one in which performance initially increases, and then might peak or stabilize. This pattern could be represented by the following hypothetical equation:

$$\mathfrak{F} = 100 - x \times e^{-y \times \mathfrak{E}} \tag{4.3}$$

An exponential decay function, denoted by $e^{-y \times \mathfrak{E}}$, is a function that indicates the possibility of declining returns as the number of epochs increases. The FI-Score is represented by the symbol $\mathfrak{F}$. Table 4.4 and Fig. 4.3 present the outcome of F1-Score with the number of epochs.

Table 4.4

Number of epochs vs. F1-Score (%)

Number of epochs	F1-Score (%)		
	Proposed	MANOVA	ANN
10	84	74	64
20	87	78	68
30	90	82	72
40	93	86	76
50	96	90	80

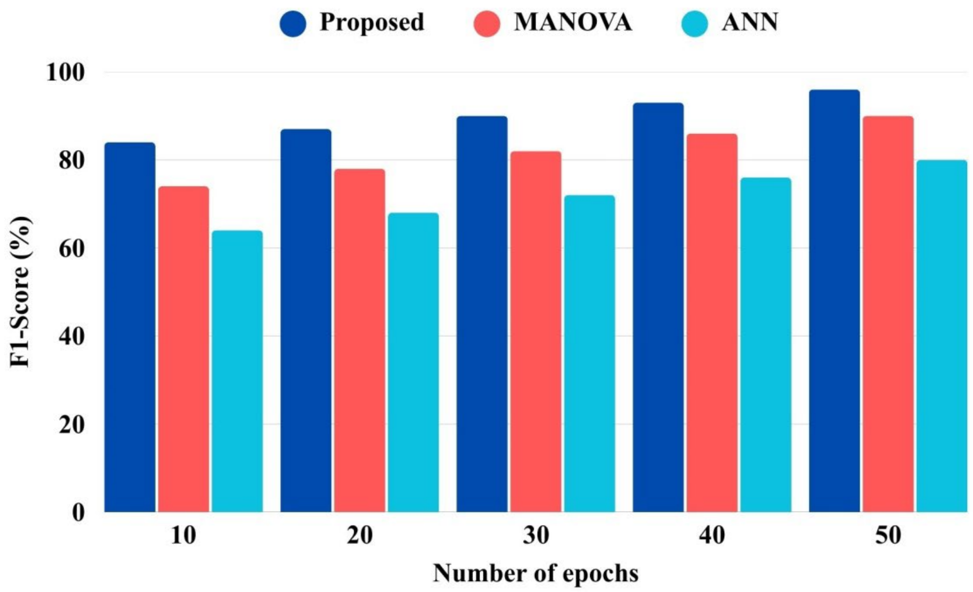

Fig. 4.3 Number of epochs vs. F1-Score (%)

The table below shows a comparison of F1-Score (%) over a variety of epochs. A comparative analysis will be performed between the Proposed technique, MANOVA. The Proposed approach consistently outperforms the others, with an initial F1-Score of 84% at 10 epochs that increases to 96% at 50 epochs. The current procedure is markedly superior than the prior one. The MANOVA method starts with an initial accuracy of 74% and gradually improves to 90%. In contrast, the ANN technique begins with an initial accuracy of 64% and steadily progresses to reach 80%. According to this data, the recommended strategy consistently produces higher F1-scores at each epoch level, indicating a better balance between accuracy and recall. Therefore, the proposed technique transcends the existing methods. The suggested methodology has the ability to get superior F1-Scores at a reduced timeframe and maintain this advantage throughout the training process, making it a more efficacious choice for accuracy-demanding activities.

4.3.4 Number of epochs vs. Recall (%)

In equation (21) illustrate mathematical representation of the suggested number of epochs vs, recall (%). $\mathcal{R}$ demonstrate the recall.

$$\mathcal{R} = y \times \ln(\mathfrak{E}) + z \tag{4.4}$$

ANN, MANOVA, and three separate models with varying recall percentages throughout many epochs are graphically shown in Table 4.5 and Fig. 4.4 that have been provided. Recall is a performance statistic that takes into account a model's capacity to accurately identify all instances that are relevant to the problem at hand. All models show an improvement in recall as the number of epochs grows, which indicates that an increase in the number of training repetitions typically results in an improvement in the performance of the models.

Table 4.5

Number of Epochs vs. Recall (%)

Number of epochs	Recall (%)		
	Proposed	MANOVA	ANN
10	86	73	67
20	89	78	70
30	93	82	73
40	96	85	76
50	97	89	80

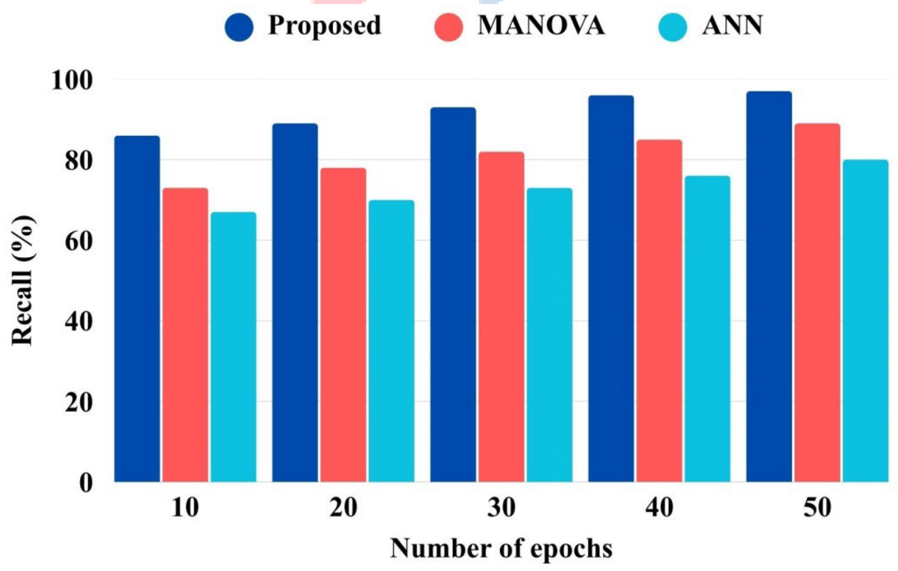

Fig. 4.4 Number of Epochs vs. Recall (%)

There are three approaches that are compared in this table: the Proposed method, MANOVA (Multivariate study of Variance), and ANN (Artificial Neural Network). The table gives a comparative study of recall (percentage) over various numbers of epochs. Starting with a solid 86% at 10 epochs and slowly growing to 97% at 50 epochs, the proposed technique constantly displays higher recall performance across the epochs. This improvement is consistent throughout the whole process. MANOVA, on the other hand, shows a progressive improvement over the same epochs, going from 73% to 89%, whilst ANN falls behind with a range that goes from 67% to eighty percent. Overall result show that the effectiveness of the proposed method is high compare to other methods of MANOVA and ANN.

4.4 Chapter Summary

This chapter first handed over the simulation setup and the specification that used for the simulation of the proposed method. Followed by the simulation and experimental results for the proposed approach which outperform in terms of prediction rate, precision, F1-Score and recall is compared with some of the existing method such as MANOVA and ANN to justify the overall effectiveness of the proposed method. The metrics which are mentioned above are inspired to their corresponding parameter such as number of epochs.

Chapter 5

Conclusion and Future Extraction

This chapter provides the design information for the identification of factors influence the effectiveness of integrative STEM education in Vietnam high schools. The conclusion for proposed models points out the possible future direction related to the identification of factor affect the integrative STEM education system in Vietnam high school.

5.1 Conclusion

In conclusion, this study provides a robust framework to improve the integrative STEM education in Vietnamese high schools. The purpose of this study is to investigate the variables that affect how well integrated STEM education works in Vietnamese high schools. By discerning these attributes, we may enhance our comprehension of the potential and challenges that arise, hence enhancing the results of STEM education and eventually, contribute to the creation of a talented and inventive work force in Vietnam. To improve the quality of subsequent analysis we using the normalization method during the pre-processing. Extract the important features from the processed data, employing DEA method to select most relevant features that improve the prediction of student prediction pass rates and academic performances. TF-ANN should be combined in a hybrid manner to forecast student achievement.

The model is combined with the DEA, which is responsible for selecting the characteristics and greatly enhancing the accuracy and efficacy. Perform a Training Needs Analysis (TNA) to identify the difficulties encountered by instructors in the context of online instruction. To develop training programs tailored to specific needs, it is necessary to use Kirkpatrick's 4 stages Training Evaluation Model to assess and address the identified difficulties. In order to improve the online experience, we first include MNI-ML to provide tailored and interactive learning experiences that encourage a more profound comprehension of STEM subjects. Research was to assess the efficacy of integrating STEM education into high school curricula in Vietnam. According to the findings, the suggested technique consistently outperforms both the MANOVA and ANN models across all of the criteria that were assessed.

5.2 Achieving Research Objectives

All research objectives mentioned at the early stage of the study have been effectively accomplished:

- **Objective 1:** Evaluate the effectiveness of online training for both teachers and students in the integrative STEM education, considering time constraints and issue.

Achievement: A detailed evaluation of online training programs was conducted, and important variables that affect the efficacy of online integrated STEM education were identified. These variables included time management, course design, and delivery techniques. The suggested technique improved online experiences by using multimedia network interpretation teaching using machine learning (MNIT-ML), resulting in increased engagement and efficiency for both teachers and students.

- **Objective 2:** In order to make sure that educators are equipped to provide high-quality teaching, evaluate the STEM education training.

Achievement: To determine the difficulties instructors, encounter while implementing online integrated STEM education, the study carried out a thorough TNA. A training program was devised and conducted based on the TNA. The efficacy of these programs was assessed using Kirkpatrick's 4 Levels Training Evaluation Model, guaranteeing that instructors were proficiently prepared to provide outstanding STEM teaching.

- **Objective 3:** Analyze the accuracy of pre-service teachers for self-reports regarding their knowledge of STEM education.

Achievement: The research examined pre-service teachers' self-reports and contrasted them with real performance indicators. The present study exposed disparities between the knowledge that participants self-assessed and their actual competency, underscoring the need for teacher training programs to include more specific and thoughtful self-assessment instruments.

- **Objective 4:** Investigates the feature selection to enhance the performances of the model in STEM education and the prediction accuracy.

Achievement: For feature selection, the study used the differential evaluation algorithm (DEA). Next, a hybrid technique combining random forest and artificial neural network (RF-ANN) models was implemented. The use of sophisticated feature selection approaches greatly enhanced the accuracy of predicting student performance, thereby highlighting the efficiency of this methodology.

5.3 Answering Research Questions

1. What specific factors influence the quality of teachers in delivering integrative STEM education in Vietnamese high school ?

Answer: To improve the teacher quality

2. How can professional development training programs for teachers be improved to better support integrative STEM education?

Answer: To enhance the quality of teacher professional development training

3. How to improve the school management, available of resources, infrastructure?

Answer: To improve the school management and the infrastructure and equipment.

5.4 Future work

Future research needs to examine the suggested method's long-term effects on student learning results and STEM engagement. Furthermore, additional research might explore the potential for this strategy to be grown up and used in other educational settings, as well as its capacity to be adapted to areas outside of STEM.

Appendix A

Data collection instruments

A.1 Interview scripts

In order to learn more about education perspective on the efficiency of integrated STEM education Vietnamese high schools, the interviews designed to gather their qualitative data. Three different types of interview styles were used to collect a rage of perspectives and to meet varying communication preferences. Interviews are a crucial component of STEM teacher training and professional development initiatives in Ho Chi Minh City. These interactions allow researchers and educators to explore the experiences, strategies, and perspectives of teachers and field experts. Conducting effective interviews can yield actionable insights, yet the process requires careful planning and execution.

This chapter provides detailed interview scripts tailored to the study's objectives, designed to facilitate productive conversations and comprehensive data collection.

- **Structured interviews:** A predetermined set questions was used in these interviews to provide uniformity throughout participants. The organized format enabled the methodical collecting of similar data. The questions focused on essential subjects such as instructional approaches, problems, and future ambitions for STEM education.

Example question: "*What challenges do you encounter in implementing STEM education in your classes?"* This question aimed to uncover specific barriers faced by educators, such as resource limitations, student engagement issues, or curriculum integration challenges.

- **Semi-Structured Interviews:** In this interview format was used to investigate new themes by posing follow-up questions in response to participants' answers because to the format's adaptable structure. Compared to organized interviews, this method sought to obtain deeper and more comprehensive insights.

For example, if a participant mentioned using project-based learning, the interviewer might ask: *"Could you elaborate on how you implement project-based learning in STEM education and the outcomes you have observed?"* This flexibility facilitated a deeper understanding of innovative teaching strategies and their impacts.

- **Unstructured interviews:** Participants were invited to openly express their thoughts, narratives, and experiences with STEM education through unstructured interviews. Participants were free to rank the topics they felt were most important, but the interviewer guided the conversation to make sure it included important subjects. The use of technology in STEM instruction, perceived lack of support from school officials, and teachers' goals for upcoming STEM projects were among the subjects covered.

STEM Knowledge and Skills

The assessment of students' self-perceived proficiency in STEM (science, technology, and mathematics) courses was the main objective of this part. It also investigated their understanding of the application of STEM. To determine any knowledge or confidence gaps that would prevent student from advancing academically or professionally in STEM-related fields.

Engagement in STEM

This section examined the active participation of students in extracurricular and curricular STEM-related activities. It also looked at how they used technology to study.

Example questions:

- "Have you participated in any science fairs or robotics competitions?"
- "Do you use educational apps or online platforms to enhance your STEM learning?"

Challenges and Supports

This section delved into the obstacles students face in STEM education and the support systems available to help them overcome these challenges. It emphasized the role of teachers, parents, and peers in facilitating STEM learning.

Example questions:

1. "What are the biggest challenges you face in learning STEM subjects (e.g., difficult concepts, lack of resources)?"

2. “Do you receive guidance or encouragement from your family to pursue STEM activities?”

Interest in STEM Careers

This section assessed students’ aspirations and interest in pursuing STEM-related careers. It also examined their perception of STEM's significance in addressing global challenges.

Example questions:

1. "What STEM career paths are you most interested in (e.g., engineering, data science, environmental research)?"
2. "Do you see STEM as a critical tool for addressing issues like climate change or healthcare innovation?"

Appendix B

Ethical Considerations

Ethical consideration was central to ensuring the integrity, transparency, and credibility of the research. Throughout the study, a methodical strategy was used to protect participants' rights and advance moral behavior. The following is an explanation of the important ethical measures that were implemented:

B.1 Confidentiality

Confidentiality was a cornerstone of the research, ensuring that participants' personal information and responses were protected at all times. Anonymization techniques were employed by assigning unique codes to participants instead of using identifiable details. All data were stored securely, with physical records kept in locked cabinets and digital files protected by passwords, accessible only to the research team. The findings were presented in aggregate form, ensuring that individual responses could not be traced back to specific participants, thereby maintaining their privacy throughout the study.

B.2 Informed Consent

Informed consent was obtained from all participants to ensure they were fully aware of the research's purpose, procedures, and implications. Participants were provided with a detailed explanation of the study in accessible language, including its objectives, any potential risks, and benefits. They were required to sign consent forms confirming their understanding and agreement to participate, while minors provided consent through their parents or guardians. Ample opportunities were given for participants to ask questions or seek clarification, ensuring they entered the study willingly and with complete understanding.

B.3 Voluntary Participation

Participation in the study was entirely voluntary, emphasizing respect for participants' autonomy. They were informed that their involvement was optional and that they could withdraw at any time without providing a reason or facing any negative consequences. This reassurance was vital in creating a comfortable environment where participants felt free to make their own decisions about involvement. The recruitment process was designed to avoid coercion or undue influence, ensuring that every participant's choice to contribute was made independently and freely.

Appendix C

Data Analysis procedures

In order to guarantee a comprehensive study of the information gathered, the data analysis procedure included both quantitative and qualitative methodologies. The data gathered from the teacher and student surveys was the subject of quantitative analysis, which employed statistical methods to find trends, patterns, and correlations. This method made it possible to uncover important connections and gain understanding of the experiences, difficulties, and viewpoints of students as well as the opinions of educators on STEM education and its application. Transcripts of interviews were methodically examined and categorized in order to find recurrent themes for the qualitative analysis. These topics emphasized important facets of instructional techniques, difficulties in providing STEM education, and the general efficacy of present methods. Combining these two methods allowed the study to bridge the gap between contextual insights and numerical data, offering a comprehensive comprehension of the research findings.

C.1 Quantitative Analysis

Quantitative analysis involved the statistical examination of data collected through student and teacher questionnaires. Responses were numerically coded and analyzed using statistical software to uncover patterns, trends, and relationships. Descriptive statistics were employed to summarize the data, providing insights into the participants' demographics, confidence levels, and engagement with STEM education. Inferential statistical techniques, such as correlation and regression analysis, were applied to identify significant associations between variables, such as students' confidence in STEM subjects and their participation in related activities. This method provided measurable and objective results that informed the broader understanding of STEM education's challenges and opportunities.

C.2 Qualitative Analysis

Qualitative analysis focused on interpreting the narratives from interview transcripts to gain deeper insights into participants' experiences and perspectives. The data were meticulously coded to identify recurring themes and patterns, such as effective teaching strategies, common challenges, and the perceived impact of STEM education. The thematic analysis emphasized the nuanced understanding of teacher and student experiences, highlighting qualitative aspects like emotional engagement, motivation, and contextual barriers. This approach complemented the quantitative findings by providing context and depth to the numerical data, enabling a more comprehensive understanding of the research objectives.

Appendix D

Student Survey Results

D.1 Overview

The student survey aimed to gather insights on students' confidence, engagement, challenges, and aspirations within STEM education. A total of responses was collected, providing a comprehensive dataset to analyze students' experiences and perspectives. The results highlighted various trends in confidence levels, participation in STEM activities, and interest in pursuing STEM-related careers.

D.2 Sample Questions and Responses

Confidence in STEM Abilities: Students demonstrated mixed confidence levels, with most responses falling under Neutral or Agree for statements like "I am confident in my math abilities." A significant number of students expressed Strongly Agree when asked about their use of technology in learning.

Engagement in STEM Activities: Participation rates in STEM-related activities within schools were low, with many students selecting No for questions about their involvement.

For extracurricular STEM activities such as workshops or competitions, responses predominantly ranged from Rarely to Sometimes, indicating limited engagement outside regular curriculum.

Interest in STEM Careers: Despite challenges, the majority of students expressed a strong interest in STEM careers, with fields such as Engineering and Science being particularly popular. This underscores the aspirational value of STEM education among students.

Appendix E

Teacher Survey Results

E.1 Overview

The teacher survey sought to evaluate educators' perceptions of STEM education, focusing on its effectiveness, the challenges they face, and areas needing improvement. A total number of responses were collected, offering valuable insights into the teaching landscape of STEM education.

E.2 Sample Questions and Responses

STEM Education Effectiveness: A consensus emerged among teachers, with all respondents agreeing that their experience with STEM education was effective. This highlights the confidence teachers have in their instructional practices and content knowledge.

Challenges in Teaching STEM: Teachers widely acknowledged the challenges associated with teaching STEM subjects, with most responses distributed between Agree and Strongly Agree. These challenges included addressing diverse student needs, resource limitations, and keeping up with evolving STEM curricula.

Teacher Training Programs: Responses to questions about professional development programs were generally positive, with a majority indicating Strongly Agree or Agree. This reflects satisfaction with the quality and relevance of current STEM teacher training initiatives, though some responses hinted at room for improvement.

Appendix F

Analytical Methods

F.1 Overview

In this part, a comprehensive overview of the analytical methodologies and tools that were used in the process of analyzing the data from the survey is presented. The methods, models, and strategies that were applied in order to generate insights and implications from the collected data are included in what follows.

F.2 Analytical Methods

Algorithm selection: Initially, we conducted interviews with educators to gather qualitative data and explore their perspectives on the effectiveness of integrative STEM education in Vietnamese high schools. The interviews were designed to provide a comprehensive understanding of the challenges, successes, and potential improvements in STEM education. To accommodate diverse communication preferences and ensure a wide range of insights, the interviews were conducted in three different formats. To perform the z-score normalization during the pre-processing to improve the standardization and comparable data across different features that improves the quality of subsequent analysis. To employ the DEA to select the most relevant features that improve the prediction of student prediction pass rates and academic performances. To develop a hybrid approach to combining TF-ANN to predict the student performances. The model integrated with the DEA that selects the features and significantly improves the accuracy and effectiveness. Conduct TNA to identify challenges that faced by teachers in online teaching.to design need-based training programs to overcome the issues that is evaluated using Kirkpatrick's 4 levels Training Evaluation Model. To enhance the online experience first we implement the MNI-ML to create the personalized and interactive learning experiences that promotes the deeper understanding STEM concepts. To develop the QA framework to STEM fields that emphasis the outcome based virtual courses with active learning practices. To utilize the fuzzy logic to monitor the student performances, offer valuable insights for timely intervention and improvements.

F.3 Implementation Details:

Differential Evolution algorithm (DEA): Used to optimize feature selection by evaluating the contribution of each feature to the prediction of student pass rates. The DEA method effectively identified the most relevant features for model training.

Random Forest - Artificial Neural Network (RF-ANN): This ensemble model integrated the strengths of Random Forest for robustness and Artificial Neural Networks for non-linear feature interactions. Parameters such as tree depth and number of neurons were fine-tuned to optimize prediction accuracy.

Training needs analysis (TNA): Based on the TNA findings, a tailored training program was designed to address identified issues. The effectiveness of these programs was evaluated using Kirkpatrick's 4 levels Training Evaluation Model, which assesses reactions, learning, behavior, and results to gauge the impact of training initiatives.

Fix-and-optimize heuristic combined with a Variable Neighborhood Descent Method (FOH-VDM): This method utilizes decomposition strategies at the class, teacher, and daily facility scheduling levels to enhance efficiency and resource allocation.

Multimedia Network Interpretation Teaching using Machine Learning (MNIT-ML): MNIT-ML integrates multimedia resources with machine learning algorithms to create personalized and interactive learning experiences for students. This approach facilitates a deeper understanding of STEM concepts and fosters knowledge transmission through modern teaching techniques.

Fuzzy logic: Monitoring student academic performance is critical for identifying areas of improvement. Fuzzy logic, a form of artificial intelligence, was utilized for this purpose. By analyzing factors such as attendance, participation, and assessment scores, fuzzy logic provides valuable insights into student progress and enables timely interventions to support learning outcomes.

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