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Project Based Learning and Integrated STEM-IT Education for 21st-Century Skill Development

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Abstract—**We are living in an era of digital transformation, where newfangled technologies are continuously changing the ways of life around us. The next generation industrial revolution is driven by the disruptive technologies such as Artificial Intelligence, Internet of Things, 3D printing, AR, VR, Blockchain, Big data etc. Therefore, the challenges posed by the next generation industry driven by these disruptive technologies are big. One of the greater challenges is to prepare workforce for the future digital economies encompasses Human-Machine and Machine-Machine working environments, where most of the jobs will be taken by the machines and new kind of skill-based jobs will be created. In that scenario, there is a great responsibility posed on the shoulders of today`s educational setups to adapt holistic approaches to develop 21STCentury skills in pupils to get them ready for future. This research article sheds light on the challenges posed by digital industrial revolution and the importance of STEM and digital literacy at basic education level. The article also showcases that how educational technologies supports the Project-Based Learning approaches and thus deliver the purpose of skill development in young learners. Finally, the article provides a framework for Project-Based Integrated STEM and ICT education Learning to inculcate required skills in young learners at K-12 educational levels.**

Index Terms—**Project based learning, STEM education, ICT Learning, 21st Century skill development, fFourth Industrial Revolution**

I.   INTRODUCTION

The Digital Economy (DE) is an economy which involves digital technologies and electronic communication for its economic and commercial activities [1]. The component of the Digital Economy includes Internet, digital data, electronic devices, disruptive technologies such as AI, E-Commerce, Digital platforms, and social media. Whereas, the characteristics of DE are internet availability and connectivity, personalization, mobility, automation, networking, mobility, and ubiquity as shown in Table 1.

We argue here that in future the DE will be more adhere to automation. As a result, the traditional jobs will be taken away by machines and new jobs with new skill requirements will be created. As, today we are experiencing already this phenomenon. About 1.7 million manufacturing jobs have already been taken up by robots since 2000, including 400,000 in Europe, 260,000 in the US, and 550,000 in China [2]. We can say the skill-based jobs will be created. Therefore, to address this challenge, a skillful human resource would be needed with minds to think and create.

The next generation industrial revolution requires skilled workforce filling the jobs related to cybersecurity, digital content creation, product management, digital marketing and E-Commerce, artificial intelligence and IoT related, Fintech and digital Finance, remote work solutions and digital tools, cloud computing, smart city solution creation and infrastructure, and educational technology. All such above mentioned fields demand knowledge-based skills [3]. Therefore, in this research article, we propose that Integrated STEM and ICT education based on project-based learning is the way to develop such skills in young learner.

This article is divided into four sections, first section presents the introduction. The second section discusses the challenges posed by the digital industrial revolution. Third section explains the PBL approach and integrated STEM and ICT learning for young learners at K-12 level. Fourth section proposes the framework for PBL based integrated STEM-IT learning. Fifth section concludes the paper and provide the future research directions.

TABLE1. COMPONENTS AND CHARACTERISTICS OF DE

Components of DE	Characteristics of DE
Internet	Connectivity / Availability
Electric Devices	Mobility
Social media	Personalization
Disruptive Technologies	Networking
Digital Data	Automation
Digital Platforms	Ubiquity

E-Commerce	Digital Content

I. 21ST-CENTURY SKILL DEVELOPMENT

A. Fourth Industry Revolution and its Challenges

The fourth industrial revolution is a term coined by Klaus Schwab, founder and executive chairman of the World Economic Forum, explains a world where individuals move between digital domains and offline reality with the use of connected technology to enable and manage their lives [4]. The first industrial revolution brought a change in the world from an agricultural and handicraft economy to one dominated by industry and machine manufacturing. Second Industrial revolution was triggered by oil and electricity. In the third industrial revolution, information technology was used to automate production. Now we are experiencing the fourth industrial revolution which is driven by the disruptive technologies, digitalization and sustainability.

The automation, and AI has already transformed our world drastically. New kind of jobs such as application development, digital media and marketing, cloud computing, smart city solution development and infrastructure, blockchain and bitcoin, gamification and AR/VR platform development, and many such jobs. The traditional jobs will be taken away by machines and new jobs with new skill requirement will be created. The next generation workforce will face huge challenge of new skill requirements if this problem is not addressed now.

B. Skills for 4IR

The Skill development for 21st-century is taken up automation, priority agenda by worlds prestigious organizations such as, organization of economic cooperation and development (OECD), Frameworks for 21st century skills, United Nations Educational, Scientific and Cultural Organization (UNESCO), and European Union (EU), and United Nations Educational [5] [6].and AI has already transformed our world drastically. These organizations have reported on the need of skill development and adoption of digital literacy and knowledge construction [7]. It is also noted that 21st century skill development requires competent and well-prepared teachers to deliver the task, therefore teacher training must be the part of the whole process.

21st-century Skills such as computational thinking, critical thinking, digital literacy, analyzing thinking, problem-solving skills, design thinking, idea creation and solution development, communication, collaboration and testing and validating are some of the important skills as shown in Fig. 1. Such skills are required by the digitally transformed work environment, where H-M, and M-M interaction will be of routine observation [8].

II. STEM AND ICT LEARNING FOR 21ST-CENTURY SKILL DEVELOPMENT

A. Integrated STEM-IT and Skill Development

Integrated STEM-IT is teaching Science, technology, engineering and mathematics education, and ICT in one lesson form with project-based learning approach. In such an integrated way we can develop skills in young learners for real life problems. This form of interdisciplinary education with PBL approach is called as Integrated STEM-IT. In this era of digital transformation, scientific knowledge creation and digital literacy development is need of the time. We argue here that mathematical education must include coding and programming as basic subject to teach [9].

Multidisciplinary Integrated STEM-IT approach with PBL methods, focuses on construction of scientific knowledge from different disciplines. In STEM-IT class, learners can work on a problem to solve and create a solution that requires them to design a solution by thinking all the technical, scientific, ethical and environmental aspects. Such a kind of learning approach facilitates learners to foster creative, analytical, critical thinking, and ethical skills that are essential for addressing the challenges and embracing the opportunities in continuously transforming world [10].
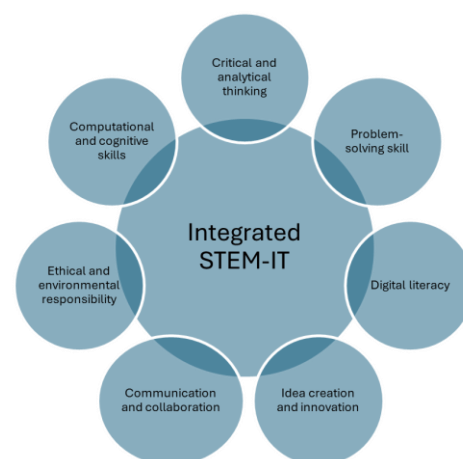

Figure1. STEM-IT Skills

B. Project Based Learning

PBL is student centric inquiry-based learning, were students start with a question or problem, often an open-ended or complex issue, that requires critical thinking and research to solve. PBL is focused on student`s choice and voice, real world relevance, and collaboration and

interaction. Students feel freedom to think and create with critical and analytical thinking [11]. With integrated STEM-IT approach shown in Fig. 3, based on Scenario-based learning (SBL) / /PBL), learners can immerse themselves in realistic scenarios where they apply their knowledge to solve complex problems involving [12].

It is evident that educational technologies support PBL. There is research done [13] shows that how Gen AI can help in STEM learning class. Students can use research and information tools such as web browsers, search engines. They can collaborate by using collaborative tools, interact with multimedia tools, can create innovative designs, presentations, and videos by using interactive design tools, can present and communicate their work with communication and presentation tools. Learners can do self-assessments by using different digital assessment and feedback tools. They can connect the world through social media platforms and share their results and get feedback and comments from real life audience.
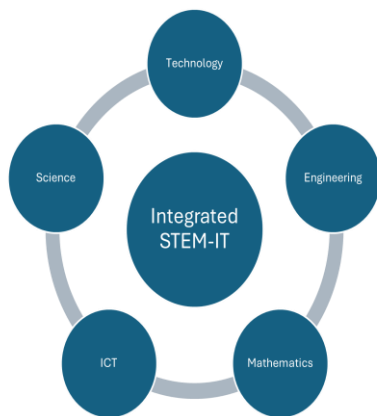

Figure. 2   Integrated STEM-IT Learning

III.   FRAMEWORK FOR STEM AND ICT LEARNING

A.   PBL-Based Integrated STEM-IT Framework

We propose here a framework for integrated STEM and ICT education called STEM-IT framework as shown in figure Fig, 4. The STEM-IT framework is based on the integrated approach as the STEM and ICT subjects include as the topics and after crafting the problem, the learners need to develop a project to solve the problem and create the solution. During this process, the learners need to explore all the aspects of STEM and ICT, they collect the scientific knowledge, they think and create the solution, they analyze, they test and validate, they use the digital tools and hence practice the digital literacy process [14]. Therefore, this whole process does not involve one or two subjects rather it involves the topics from different

disciplines in integrated form. we see here that how we can develop a certain skill set in young learners by applying PBL approach in integrating STEM and ICT lesson.
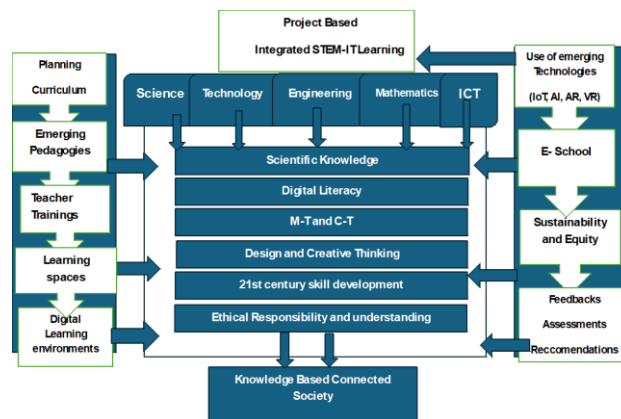

Figure. 3   STEM-IT Framework

The features of the framework are as follows:

- **Interdisciplinary Curriculum development:** An **interdisciplinary approach** for curriculum development is needed to teach science, technology, engineering, mathematics, and ICT subjects in such a way that the pupils gain knowledge and at the same time develop related skills. Therefore, there is a dire need of developing an interdisciplinary curriculum which focuses the skill development and knowledge creation, which would focus all these subjects, and the aim would be to develop the skills required for progressing in life and work situations. For example, in mathematic class teacher can help learners in developing computational and analytical thinking skills by giving them small coding problems while teaching them basic mathematics. They don't need to learn how to write code at this point, but they can think and write simple equations to solve problems and develop logical and reasoning thinking [15] [16].

- **Learning Environments**: Fast paced digital transformation and advanced technologies are the enabling key drivers of new learning spaces. Learning spaces can be brick and wall space, online or hybrid. Schools can be e-schools/distance learning schools or physical schools, classroom can be online, offline, in premises, in virtual or real environment. We argue that availability and quality of education world be equal for all. We can benefit from the digital learning tools and applications to provide such an education which is not dependent on bricks and walls rather it should be available online in the form of e-schools. During the time of COVID-19, the world has experienced that how online learning benefitted the society. We see the success of different online learning one good example is

MOOC [17]. Additionally, gaming-based learning environments like Ekapeli [18][19], successfully serving the purpose of teaching, learning and skill development. Therefore, we explain learning environments/spaces as any form from physical to online, hybrid mode and equipped with digital tools and applications powered by internet and enabling technologies.

- **Internet Connectivity and availability of electronic devices:** A connected environment with the facilitation of fast and free internet connection is the backbone of Integrated STEM and ICT framework. The availability of free internet and electronic devices to the learners enable them to focus on their learning without any stress and pressures. We must say that in a highly connected environment of learning where the digital applications and platforms are dependent on internet, a free and stable internet and electronic devices like laptops/tablets is crucial to the STEM-IT class.

- **Skill Development:** The main purpose of STEM-IT education system is to develop 21st-century skill such as digital literacy, mathematical and computational thinking, analytical thinking scientific knowledge, design and creative thinking, ethical responsibility and understanding etc. [20]. These skills are crucial to develop in young learners as they are growing in this digital age and will work in digitally transformed and automated environments with machines. STEM education along with ICT literacy integrates different disciplines to instill 21st-century skills especially 4C`s of STEM education (creativity, critical thinking, collaboration and communication). This digitally transforming world needs skilled workforce and STEM [21] and ICT education is a solid solution to this problem [22].

- **New Pedagogical Approaches**: With advancement of educational technology, the approaches to teach and facilitate the learning has also transformed and continuously transforming. The emerging pedagogies are based on different constructs such as textual, visual, audio, gaming, reading and writing, and immersive experiences using AR/VR. The emerging approaches to guide and facilitate learners must be applied for skill development and knowledge to meet the needs of digitally transformed and automated society in which H-M, and M-M interaction would be the key element. We argue here that Project- based learning with student centric approach with the twinning of other approaches can serve the purpose well [23]. Additionally, design-based learning, and scientific method-based learning are the approaches which develop problem-solving thinking, design thinking and creativity, and innovation thinking in young learners at K-12 level [24].

- **Educational Technologies:** Educational Technologies based on disruptive technologies such as AI, IoT, AR, VR, and robotics. Digital tools and applications based on these technologies such as collaborative and interactive learning platforms, gamified learning platforms, virtual classrooms, educational robotics, e-learning platforms, online courses, and digital tools for assessments and feedback, are driving the educational set ups of this digitally transformed world[25].

- **Teacher training:** Teacher training is crucial for adapting integrated STEM and ICT learning as in most cases teachers failed to understand the meaning of integrated approach. Therefore, a special training for science and ICT teachers is required to train them as the facilitators of integrated STEM and ICT learning in a student centric way. Content knowledge, quality pedagogy and self-efficacy are the important skills for STEM teachers to develop [26].

- **Sustainability and Equity:** There should be sustainability and equity factor. Any solution which is sustainable and available to all is going to deliver the purpose. Therefore, STEM-IT relies on sustainability and equity [27]. Quality education for all is the key to success in life and sustainable quality education for all opens the ways for success and sustainable development. Therefore, it is necessary to provide equal and quality education to all keeping in mind millions of children in developing countries out of school or incapable to afford education due to poverty. Therefore, we should provide such solutions which are easily available to all and of same quality for sustainable development according to UN´s sustainable development goal 4, which promotes the inclusive and equitable quality education and promote lifelong learning opportunities for all [28].

- **Bridging the gap:** Millions of children are unable to join schools and learn. We can bridge the gap by taking advantage of distance learning and setting up E-school, so the governments with minimum resources can also provide good quality education to the children [29] as required by the Sustainable development goals of United Nations [30]. Bridging the gap is crucial, otherwise we will be having one part of the world with all the facilities and skilled education to prosper and progress, while the rest of the world will be struggling for basic education. This situation of course will lead to no sustainability.

- **Knowledge based Connected Society: Project-based Integrated** STEM-IT education is focused on skilled based knowledge oriented connected society. A society, which is knowledgeful, skilled, sustainable, inclusive and adheres to the ethical responsibility. A society, where humans and machines work together with humans in center role. Digital economies based on knowledge based,

skilled and connected society would be sustainable and prosperous [31].

I. CONCLUSION

We conclude that STEM and ICT education at early education level is crucial for the development of next generation skilled workforce. We argued that integrated form of STEM and ICT learning is effective and helps in developing 21st- Century skills in pupils. Project-Based learning approach is well suited approach for integrated STEM and ICT learning. We discussed in this article that emerging technologies support PBL approach in many good ways. For bridging the gap between developed and developing countries, we can take advantage of online learning and E-school concept. Finally, we proposed a framework for Integrated STEM and ICT learning for K-12 educational settings to develop a skilled and knowledge based connected society.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

The author KZ contributed as the first author of the article. KZ conducted the research and wrote the paper.TH and PN supervised the research work, provided their valuable feedback, and arranged funding to support the work. All authors had approved the final version.

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