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STEAM Education: In Connection with Atal Tinkering Lab

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Abstract

This study explores the evolving concept of STEAM (Science, Technology, Engineering, Arts, and Mathematics) education and its implementation through India's Atal Tinkering Labs (ATLs) in alignment with the National Education Policy (NEP) 2020. The primary objectives are to examine learners' perceptions of STEM and STEAM, identify key elements and challenges in implementing STEAM education, assess its significance through ATLs, and propose strategic recommendations. Adopting a qualitative, descriptive research methodology, this study relies entirely on secondary data sources including academic literature, government policy documents, and ATL implementation reports. The findings highlight a positive shift in educational discourse toward interdisciplinary and hands-on learning, with STEAM education offering enhanced opportunities for creativity, critical thinking, and 21st-century skill development. However, the study also uncovers challenges such as lack of teacher training, infrastructural deficiencies, socio-economic barriers, and limited awareness, especially among rural and female students. The conclusion underscores that integrating STEAM education via ATLs can bridge the gap between theoretical and practical knowledge, fostering holistic development. For its effective implementation, systemic support, teacher capacity building, and community awareness are essential. This study contributes policy-relevant insights and pedagogical strategies for mainstreaming STEAM education

in Indian schools.

Keywords: STEM Education, STEAM education, 21st century skills, implementation

Introduction

All nation has their own educational system; which is constantly changing according to new demands. So, it necessary for improving new education system. In the year 1990s, STEM Education, first used by U.S, for improving the performance of science and mathematics test, like PISA Assessment. Then, in the year 2001, STEM education starts with National Science Foundation (NSF). Then, from the year of 2006, STEM Education, gave a new concept STEAM Education, as 'A' denotes as 'Arts', a holistic term. The full form of STEAM (SCIENCE, TECHNOLOGY, ENGINEERING, ARTS AND MATHEMATICES). Then in the year 2008, Georgette Yakman, develop new STEAM framework, as an educational model.Then in 2010, STEAM education, widen, in the international countries such as Australia, korea and other European countries. At the year 2016, under the initiative of NITI Aayog's (ATAL INNOVATION MISSION), develops, Atal Tinkering Lab. Then, in the year 2020, our new education policy (NEP 2020), also gave emphasis on STEAM Education; as this policy belief on interdisciplinary learning. STEAM Education was connected or related with software development, technological development, computer science, information security and arts related subjects (Gomez 2013). New education policy (NEP2020) suggest that the education system should be based on STEAM education. STEM education focus on scientific concepts, but STEAM focuses on science as well arts concepts. Hence, the learner can able to think logically, creatively and artistically. STEAM education is a multidisciplinary and interdisciplinary approach. It is a learner-centered approach, where the learner learns things by learning by doing process; so that the learner should confront along 21st century skills. The new era gives more emphasis on metacognitive abilities (Mooney, 2002). STEAM education deals with constructivist approach, as the learner construct their own knowledge. The two main points for STEAM education is – first, is to increase the employment rate of the students after completing STEAM education and second, is learner should competent to learn basic things of STEAM field (Thomasian, 2011).

STEAM education not only enhance the creativity skills, logical skills; but it also enhances the communication skills such as writing skills, reading skills and speaking skills; as because it deals with arts field (Armknech, 2015). STEAM education deals with realistic and practical system. STEAM is very requisite for the evolution of the 21st century skills between all learners; therefore, new education policy (NEP2020) supports the STEAM education for each learner (J.Doe, 2022). The expansion of STEAM

education; the alphabet 'A' 'Arts' denotes. He gives importance on the creativity of such method. He also explained that how STEAM education gives support to female students. He also says that how the STEAM education will be helpful in the educational system as it amplifies the education quality (J.Smith, 2021). The knowledge of STEAM based education among the learners. The main goal of this research is to found out the knowledge gap; as well as to suggest the various strategies to strengthen the STEAM education in the academic system. In this research work the result was highlighted that the majority pupil knows about STEAM education but how to prosecution the STEAM method and by what means it can be significance to the pupil cannot be easily understandable by the other people. So, Dr. Done in his research work discussed about the prosecution of STEAM education in his findings (J.Done, 2021). The education is the most important tool, to live with secured life, as it can improve the condition of human life. The teaching-learning process is unable to isolated from the sphere of education. In the teaching-learning process the interconnection through the pupil and teacher is very much important and by this interaction the information sharing can also be enhanced (Koehler et al, 2013).

Atal Tinkering Lab was developed by Central government, under the sub-mission of Atal Innovation Mission. This lab initiative was under NITI Aayog. It was launched at year of 2016. From this type government initiative, more than 1.1 crore learners get benefited. Every school should adopt Atal Tinkering Lab for enhancement of STEAM Education.

The existing literature on STEAM education provides a vital foundation for this study by highlighting its evolution, pedagogical value, and global relevance. Prior research emphasizes the transition from STEM to STEAM, underscoring the importance of integrating arts to foster creativity and holistic problem-solving among learners (Yakman, 2008; Liao, 2016). Studies by Eisner (2002) and Peppler & Wohlwend (2018) support the argument that arts-based learning enhances cognitive development and innovation—key outcomes aligned with 21st-century skills. These insights reinforce the relevance of STEAM education in today's context and justify the need for its widespread adoption in schools. Furthermore, policy-level discussions, especially those aligned with India's NEP 2020 (Sharma & Guha, 2024), stress the importance of experiential and interdisciplinary learning, directly supporting the integration of STEAM principles through Atal Tinkering Labs. The literature also identifies gaps such as inadequate teacher training, socio-economic barriers, and limited infrastructure (Marcus, 2021; Tally & Ortiz, 2017), which this study aims to explore in the Indian context. Thus, the existing body of work not only frames the theoretical and policy background for this research but also helps in identifying the specific challenges, opportunities, and research gaps that this study seeks to address.

This research contributes to the academic discourse and practical application of STEAM education in the following ways:

Contextual Insight: It provides a unique contextual exploration of how STEAM education is understood and practiced within Indian schools through the Atal Tinkering Lab initiative, filling a regional gap in the global STEAM education discourse.

Implementation Analysis: It offers a qualitative assessment of the implementation challenges and systemic gaps that hinder effective STEAM education through ATLs, which has been under-researched.

Pedagogical Recommendations: The study proposes specific, practical strategies for improving STEAM pedagogy and policy recommendations for teacher training, infrastructure development, and inclusive practices.

Policy Alignment with NEP 2020: It aligns the findings with the goals of India's National Education Policy (NEP 2020), offering policy-relevant insights for future educational reforms.

The American country first coined the STEM learning model, because this country focuses on how to upgrade the performance of PISA (Programme for International Student Assessment) test. The US National Science Foundation held an interagency conference on science education; first the term STEM came into force (Fioriello, 2014). After the year of 1996, it is commonly used (Korbel, 2016). Hence, they first try to enhance in the discipline of science stream and then they combined with Technology and Engineering field. So, then the STEM education was come out. The STEM model is the mixed up of four streams that are interconnected with others to solve hard problems and also present days problem (White, 2014). Recent time, few learners follow STEM model is very low, because Art is not incorporate at STEM model which is very much creative for the learners and they also think innovatively. If the students think creatively and critically then the STEAM students will able to solve problem easily (Slavit et al, 2016). So, now the new model of learning STEAM(STEM+ARTS) has flourished. It is very much for having artistic skills to develop, for presenting work. The STEAM is now available in international and national countries.The science education learners have different range of attitudes, knowledge, interest and competencies. They try to understand different learning facts in term of doing experiment. They are involved in various research and innovation work. Their interest and excitement to know abundant things which are related to the natural and physical world (Sotiriou, 2013). They are always tries to gather knowledge which are related to applied knowledge. Science always helps students to transfer knowledge with others and solve various problem. Students try to understand and remember the facts which is related to science (Dewey, 1938). Reasoning skills, creativity skills and analysis skills will be improved through science education. They are always tried to engage with scientific reasoning. As we know that science is not a

static thing; it is dynamic in nature; because by continuous evaluation it is day-by-day, so students are always reflecting to science phenomenon (Biesta, 2003). Students always like to participate in scientific activities with other peers and always use scientific tool. By studying science subjects, they feel or think like a scientific enterprise. Integrating technology, the students try solve technical problem with the help of science (Eisner, 2002).

The arts education learners also have different range of attitudes, knowledge, interest and competencies. They try to understand different learning facts in term of artistic view (Eisner, 2002). Their interest and excitement grew up from artistic environment and artistic expression. By arts education, students develop creativity skills. They always try to gather knowledge from artistic expression. The learners can develop new knowledge by putting into an art frame (Nielsen, 2005). Integration of Arts not only give enjoyable learning, but also enhance the learning outcomes of the learners. The concept of Arts is a very broad concept. The arts are called as fine arts which is related with language and social arts. The combination between the arts and science discipline enhances the innovation of a product design (Winner et al, 2013). Arts always give a creative model in the evolution of science. Students give important on arts related things. Learners tries to participate in various artistic activities with others peer. They always tried to demonstrate various things in a very artistic form (Borgdorff, 2012). As, project work needs artistic skills to present new things. Students always develop artistic habits from others.

Despite the growing emphasis on 21st-century skills, India's school education system continues to struggle with integrating innovative, interdisciplinary learning models like STEAM (Science, Technology, Engineering, Arts, and Mathematics) education. While the Atal Tinkering Labs (ATLs) have been introduced as a national initiative to promote hands-on learning and creativity, their practical effectiveness in facilitating true STEAM-based learning remains under-explored. There is also limited understanding of how educators, learners, and institutions perceive, adopt, and implement STEAM principles within the ATL framework. This lack of empirical insight into the practical integration of STEAM education through ATL infrastructure constitutes a significant gap in research and policy planning.

The objectives of the Study are to know about the concept of STEAM Education, study the student's viewpoint and actions about STEM and STEAM Education, identify the main key elements of STEAM Education, and look over with some kind of issues related to STEAM Education which was faced by students, teachers and stakeholders of the schools in accepting STEAM Education.

To fulfill the objectives of this study, following research questions were designed:

i. What is the concept of STEAM Education?
ii. What is the student's viewpoint and actions about STEM and STEAM Education?
iii. What are the main key elements of STEAM Education?
iv. What issues do students, teachers and stakeholders of the schools faced in accepting STEAM Education?
v. What kind of strategies the schools should follow before implementing STEAM Education?
vi. What is the significance of STEAM Education through Atal Tinkering Lab (ATL)?
vii. What is the recommendation and Educational Significance for STEAM Education?

Research Methodology

This paper overview the 'STEAM EDUCATION:IN CONNECTION WITH ATAL TINKERING LAB'. This research work is a qualitative work and follows descriptive method. This study adopts a qualitative, descriptive research design, which is appropriate for exploring conceptual, contextual, and theoretical aspects of STEAM education in connection with Atal Tinkering Labs. The objective of the study is not to measure or quantify variables, but rather to understand and explain how STEAM education is evolving, how it is being conceptualized in educational discourse, and how it aligns with national initiatives such as the Atal Innovation Mission. A qualitative approach is most suited for such exploratory and interpretive work, as it allows the researcher to analyze texts, policies, scholarly articles, and educational frameworks in a holistic and reflective manner. This study is based entirely on secondary data sources, including published journals, academic literature, policy documents (like NEP 2020), and official information about the Atal Tinkering Labs. As a result, there is no direct engagement with human participants, and hence, no need for data collection tools such as interviews, surveys, or observation schedules. Similarly, sampling procedures are not applicable, as the study does not draw from a specific population or sample group. Instead, the selection of literature and policy documents was guided by relevance to the research objectives and thematic alignment with STEAM and ATL frameworks.

Given that this is a non-empirical, theoretical study, there are no numerical datasets to analyze using statistical or coding methods. Rather than applying structured data analysis techniques, the study uses a narrative and thematic review approach to critically synthesize existing knowledge. The focus is on interpreting and connecting insights from prior studies to identify gaps, trends, and implications for educational practice.

Elements of STEAM Education

There are four basic principles for STEAM education. The first element is *learning environments*, second is *teaching methods*, third is *discipline knowledge* and last is *expectation*. The four basic principles are associated with each other and play

a predominant role in STEAM education. As, we know that the main component of teaching is the learner, teacher, curriculum and learning environments. The teaching is incomplete without this element. *Learning environment* is basic principle of STEAM education. It is predominant for having a proper learning system (McDonald, 2016). As much as the learning system is flexible and adjustable, the learner will more eager to learn quickly. There should be a proper infrastructural facility and technological facility in the classroom. In classroom setting their will be a proper community practice, STEAM related T.V program and student – teacher program. *Teaching methods* is another important element of STEAM education. The teacher can only know which methods they should adopt in the classroom teaching (Rose MA, 2019). In STEAM education, the most important teaching methods is problem solving methods, project- based learning, inquiry-based learning, team work and various Olympiad competitions (Thomas B, 2015). The teacher must know which methods is effective and to adopt for teaching according to the needs and requirements of the learners. The teacher must give opportunity to the learner to converse about different topics among their peers which will enhance the communication and creativity skills (Farhana.Z, 2023).

Discipline knowledge is another important element for STEAM education. As, STEAM education is multidisciplinary and interdisciplinary approach; so, the teacher will teach the students integrating various subjects and discipline. Learners prefer to learn when they interlinked various subjects (Caulfied J, 2020). The learner able to understand various hard concepts in a very clear way. They can also relate with real life situations. Last is *expectations*, which is another key element of STEAM education. It is quit, natural that when the students enroll in various courses, there is an expectation, that they learn various new things, so that they will become a good citizen in future (Siew NM, 2015). In the same way, when the students enroll in STEAM education, the students have the expectations that they learn various skills and STEAM education will guide the students to select right path of the career.

Issues Related to STEAM Education

Few problems connected to STEAM education. As, India is developing country, hence it is not always possible to implement STEAM education. Many students belong to the socio-economic problem. They think that this STEAM education belongs to only higher-class students, as the course fee of the STEAM education is very high (Marcus, 2021). They cannot able to afford that course. Generally, the girls are mainly deprived from their studies. In the very poor country mainly the girls were quitted from the schools and do their household work. Girls did not received support from the families (Tally & Ortiz, 2017). Families did not have the ideas about the STEAM education. From the research, it discerns, that; the girls are less interested in STEAM education, than the boys.

Girls were afraid and have anxiety about the science subject for studies. In the rural side schools, there is not proper infrastructural facilities for the implementation of STEAM education (Pelch, 2018).

In schools, proper lab facilities are very much poor. Pupils did not receive assist from technical equipment and gadgets in school for having STEAM education. The schools are not getting a proper financial aid or assist by the government. The mixing of STEAM education requires a proper materials and resources (Betancur et al, 2018). Next, the role of a teacher is necessary for actual execution of STEAM education. For effective implementation of STEAM education, the teacher's knowledge is very essential. Teacher should give innovative idea to students. Mostly, the lack of teacher's knowledge. Lots of tutor did not have the knowledge in STEAM education (Erdas et al. 2018). The tutor does not have pedagogy knowledge and skills. The planning for instructional design is very poor.

Explication for STEAM Education

It is important to address and give special attention to all girls who are belong to weaker section to come under the inclusion of STEAM education. There should be a STEAM program, awareness program and seminar; which would help the girl students and their parents to understand the importance of STEAM education and also to understand how the education for the girls is necessary for their future (Solanki et al. 2019). There will be activity- based work and project-based work for the students; which will help the students to learn various skills. For enhancing STEAM education, the students must know the reasoning and problem -solving skill from their childhood (Mustafa et al 2016).

Informal education program also helps the pupils to modify in their studies (Roberts et al, 2018). For improving in science subjects, the school education is very important for all student. There will be a proper training program for the teachers to enhance the professional development in STEAM education (Cooper et al, 2018). The teacher must have pedagogical skills and knowledge for integration of STEAM education. A proper training should be provided to the teachers for using various types of equipment, aids and to choose teaching methods in relevance to the necessity of the students (Fletcher, 2018). The administrator in schools should plan how to use infrastructure in a proper manner. The government should provide a proper financial support to each school for the effective implementation of STEAM education.

Significance for STEAM Education

As we see that our life is totally depend upon technological appliances, hence it is important to learn various types of technological work. As we know that only STEAM education can increase the economic growth of the country. Hence, it is very necessary

for studying STEAM education for new generation youths. By this new model the students able to think creatively and also magnify the imagination power of the students. The students can also learn the 21st century skills (Reeve, 2014). By using this, holistic approach the pupils able to use both sides of the brain simultaneously. One side of the brain is associate with the logic, science and math and another side of the brain is related creative imagination and some kind social awareness (Dare et al, 2014). To add the arts in STEAM subjects is flourished from doing the real practice of science and engineering subjects to draw some kind of diagram, shapes. By having the arts subject students can easily connect the artistic skills and apply such skills in realistic and creative way (Quigley, 2017). STEAM education was linked with experimental and practical methods. So, that the students learn by doing. The students work collaboratively with the peers and solve real problems. The students gathered hands on experiences (Keene, 2013). The students combine artistic skills for their project work. Mainly there is a five stage in project-based learning. Firstly, the students tried to gather various information. Secondly, the students decide the project according to their information (Smith et al, 2015). Thirdly, monitoring the project work. Fourthly, the student tests the result and at last evaluate the project work. At each step the students are actively participates and cooperatively participate and communicate with others peers. STEAM model is a learner centered approach which enhance the learners independently and actively (Hsu et al, 2011). STEAM model enhances problem solving abilities for acquiring knowledge. It motivated the students and enhance the thinking potentiality of the learners.

How STEAM education is related with Atal Tinkering Lab?

Atal Tinkering Lab is indispensable for to understand STEAM concepts practically. The students learn essence of STEAM education by learning by doing with the assist of equipment and tools. Atal Tinkering Lab is a laboratory room, where the students learn practical work which is related to STEAM. Learners cannot able to learn all things with the assist of textbooks. In this laboratory the students learn from hands on experience. In the laboratory there are various types of equipment and aid such as- 3D printer, sensor, electronic aid, robotics and internet of things (IOT). The students learn the practical work through the use of all those equipment.

Implementation

For effective implementation of STEAM education; there are few things which should be kept in the mind of a teachers. The teachers must be efficient in *professional enhancement* for proper implementation of STEAM. They must be acquainted with the curriculum of STEAM subjects (Nadelson et al, 2013). The teacher must be adaptable which method should be used in STEAM education. Teacher should participate in various STEAM related program and seminar to enhance their skills and to know about various

technological information which will be used in this type of education. For proper implementation of STEAM education, teacher's role is very important (Lesseig et al. 2016). Teacher assists the students learn various things in STEAM. The tutor embellishes the lesson plan in an effective way. Next, the quality of STEAM *curriculum* is very much important. The curriculum should not be rigid, it should be a flexible manner. As much the curriculum is flexible, the teacher itself had some belief to teach STEAM education. The textbook should be focused on practical work, which is very much important in STEAM education. Student's assessment process should be changed (Wang et al, 2011).

From the needs and capacity of the pupils, the textbook should be prepared. Another thing, it should be kept in mind that the *collaboration* with other teachers is necessary for proper implementation. Collaboration helps the teachers, to deal with different knowledge about technological advancement, which is important in STEAM education (Lehman et al, 2014). Teachers solve various challenges faced by them with the assist of collaboration with others teachers. For having partnership with museums, laboratory and other community-based centers; as the students can easily go without any cost to gain experience or to gain more knowledge from that place, which is necessary for STEAM education (El-Deghaidy et al, 2014). Next is *previous knowledge* of a teachers which is also important for effective implementation. Those teachers who studied in general course, they did not able to acquainted with STEAM education; because general courses are different from this new model of learning (Park et al, 2017). For teaching STEAM education, it will trouble-free for tutors who studied in science and technological fields. They can relate the concepts with STEAM education. Prior knowledge gives confidence to the teachers to deal with STEAM pedagogy (Bagiati & Evangelou 2015). They also understand the concepts easily.

Another important thing, for proper implementation; the teachers must take support from the *district administrator* (Reeve 2014). For taking STEAM initiative, they must take guidance from the administrator. Administrative members play a very important role when the teachers implement STEAM pedagogy. Teachers realize that the district members can only help the parents and students for understanding about the STEAM education and what things students learn from studying this type of courses. The teachers must discuss with district schools, at the time of fixing or developing new curriculum.

Results and Discussion

After doing this work and carefully go through the various journals, National Education Policy Document and various national ATL documented material; some key point has come out:

As we know that, the NEP 2020, gives much more importance on the interdisciplinary subjects and learning. Hence, the STEAM Education through Atal

Tinkering Lab is developing nationally and world widely.

The study gives importance on STEAM Education rather than the STEM Education. As the Arts help the learners to develop artistic skills, which enhance holistic development of the learners.

The Atal Tinkering Lab was launch by Atal Innovation Mission (AIM), which is a best platform for implementing STEAM Education through Atal Tinkering Lab.

The goals of STEAM education and goal of Atal Tinkering Lab are same. Both of them fosters critical thinking, creativity, hands on experience, problem solving and to develop knowledge with real world setting.

For implementing STEAM education, the schools should focus on some essential pedagogical changes, such as changes in the curriculum, teaching methods, evaluation methods for running successfully STEAM Education.

The findings of the study are as follows:

From the study it can be understood, that Atal Tinkering Lab helps the students to do practical work through hands on experience, as well as, STEAM education helps the students to enhance theoretical knowledge by studying interdisciplinary subjects. So, this two concept, break the gap between theoretical and practical knowledge. There is a lack of knowledge among the teachers for handling STEAM Education. Female students, mostly who are belong in rural areas did not get the support from families for studying STEAM education. There is a lack of infrastructure, funds, technical, technological support in the schools for implementing STEAM education. The society must arrange some awareness programs for the students, parents and administrator for knowing the importance of STEAM education. There is a gap of knowledge between the educators and policymakers for adopting practical application and there is a difference between STEM and STEAM education.

Conclusion

At last, we can conclude that, as the world is constantly changing, it is significant to upskill the new generations with technological skills, engineering skills, 21st century skills and various types of design skills; so, pupils able to play significant role in the scientific and economic development. From the study, it is found the students will gain or achieve at least five components – expectations, structure the knowledge, able to do problem solving, to do practical work and at last metacognitive power. STEAM education the enhance the cognitive and conceptual based understanding by the help of five discipline. The learners will achieve mastery in the science, technology and arts subjects. STEAM is also helpful in the inclusive classroom. The students can learn in the form of independent manner, where the teacher's role is just like a facilitator. In STEAM education the learner mainly uses inquiry method to learn scientific concepts. The learner

will gain the ability to think and develop ideas creatively. So, there must be a trained teachers to instruct their learners. Hence, STEAM education in higher level institutions will aid the pupils to deal with the first changing environment and also enhance the economic development. The institutions can take highly eligible worker and always inspire the innovation and development of the society. From the above, it can understand that how much the STEAM education is significant for the student's life in future. So, it is essential for having Atal Tinkering Lab in every school for comprehend the STEAM education in an effective way.

Recommendation and Implication

The administrator should arrange various types of seminars, conference and colloquiums related to STEAM education. Proper training program is also necessary for the teachers to enhance the professional development skills for preparing the content or lesson and pedagogy of STEAM education. The teacher should rearrange the textbook in such a way which is relevant to STEAM education. The textbook should focus on theory as well as practical work. For understanding, how STEAM education will be important in future days, to the parents and students, the school administrator should arrange various community programs. It is very much necessary to upgrade and modify various science aids and equipment and proper infrastructural facilities. The administrator should arrange diagnostic test for teacher's assessment for having competent in their skills and knowledge in STEAM education.

Pupils perceive out different chance for their upcoming development. By their creative skills the students can create learning surrounding in a very interesting way. The government can arrange different program, seminar, workshops for both teacher and students at a very low cost; so that everyone can able to participate. The Government will assist financial support to all schools for better infrastructure and also provide scholarship to those students who want to pursue STEAM education. There should be an expert or researcher to develop and modify STEAM education if necessary. School administrator can change the mind of the parents and students for getting STEAM education. By this new model of learning the teachers will eager to learn new concepts and skills.

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