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Rote to Robot: The STEAM Revolution – Content Analysis of STEAM Curriculum

Abstract

The present study focused on analysing the STEAM curriculum. The current study based on following objectives. (i) To analyse the content of science, technology, engineering, arts and mathematics STEAM curriculumm. (ii)To investigates the challenges faced regarding implementation of STEAM curriculum. (iii)To identify the strengths and areas of improvement of STEAM curriculum. Qualitative content analysis research design employed. Purposive sampling techniques were used. Sample of the study consisted of ten chapters from each STEAM curriculum textbook of grade one two and three. It was shown by the results of the study that the STEAM curriculum has potential to inculcate both soft and hard skills in students through transdisciplinary learning. However, gaps exist in contents integration, teacher's training, resource availability. It was concluded that systemic changes in in-service and pre-service teacher trainings, instructional support, and policy direction needed for successful implementation of STEAM curriculum.

Keywords: Content Analysis, STEAM, Curriculum, Textbooks

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Abstract

The present study focused on analysing the STEAM curriculum. The current study based on following objectives. (i) To analyse the content of science, technology, engineering, arts and mathematics STEAM curriculumm. (ii)To investigates the challenges faced regarding implementation of STEAM curriculum. (iii)To identify the strengths and areas of improvement of STEAM curriculum. Qualitative content analysis research design employed. Purposive sampling techniques were used. Sample of the study consisted of ten chapters from each STEAM curriculum textbook of grades one, two, and three. It was shown by the results of the study that the STEAM curriculum has potential to inculcate both soft and hard skills in students through transdisciplinary learning. However, gaps exist in contents integration, teacher's training, resource availability. It was concluded that systemic changes in in-service and pre-service teacher trainings, instructional support, and policy direction needed for successful implementation of STEAM curriculum.

Keywords:

Content Analysis, STEAM, Curriculum, Textbooks

Introduction

Currently, education systems are under significant pressure to produce a workforce skilled in meeting the demands of the upcoming job market one that requires individuals who are problem-solvers, critical thinkers, and creative, with strong communication skills. Therefore, STEAM (science, technology, engineering, arts and mathematics) education, is a modern and evolving concept intended to address this requirement. Curricula based on STEAM education approach founded on an integrated, transdisciplinary learning. Unlike traditional education approaches, which offer little room for the development of students' creative skills, STEAM education provides a more appropriate framework for enhancing divergent and innovative problem-solving abilities among students.

Therefore, the introduction of the STEAM curriculum at the elementary school level helps establish a strong foundation for lifelong learning. Furthermore, early exposure to STEAM education can significantly improve creativity and problem-solving skills in students (Yakman & Lee, 2012).

However, in the current educational landscape, the successful implementation of STEAM curriculum depends on various factors, such as teacher education, community awareness, resources, teacher training, and student attitudes toward the STEAM approach.

Background and Context of the Study

The education approach STEM stands for Science, Technology, Engineering, and Mathematics it is based on practical and experimental learning by utilizing problem-based and experiential, and discovery learning teaching methodologies. However, the term STEM was first presented as SMET in 2001 by Judith Ramaley director of National Science Foundation, United States of America. The basic objective behind the STEM education approach is to renovate science, technology engineering and mathematics education in US colleges and universities (Kainat, 2020).

Therefore, all Government and private organizations worked on the STEM education approach. Moreover, the STEM principles of education were applied in curriculum creation in an enormous number of tertiary educational institutes in the United States of America. Furthermore, the requirements in STEM disciplines have transformed the educational landscape in America, and as a result more than thirty to forty million professions arose in commercial sector. However, to change the orientation of STEM from technology to humanity fifth component Arts added to the STEM disciplines to in 2015. Therefore, the addition of Arts was considered necessary to make STEM more holistic concept. The concept of STEAM education was introduced during a longitudinal survey conducted by national education foundations of America (Khan & Mangi, 2025). Therefore, STEAM education emerged as innovative and more holistic concept with more human values by blending of arts and technology together. In this way STEAM education approach have the capability to make technology more human-centered by merging the fifth discipline Arts with STEM. Therefore, the STEM idea was gradually developing into a more holistic concept STEAM (Kainat, 2020).

However, contrary to outdated teaching models the science technology, engineering, arts, and mathematics STEAM education framework hazes the boundaries across disciplines to develop more advanced levels of creativity and problem-solving skills. Additionally, this educational approach, equip the future engineers, with the ability to perceive their thoughts in a more creative way by adding the flavor of the arts. Ultimately This will become more effective and creative in their profession. (Benek & Tiryaki, 2025).

Furthermore, STEAM Curriculum reflects the integration of its five components which are science, technology, engineering, arts, and mathematics in a well-balanced way. However, this blending of STEAM disciplines requires project based, inquiry based, and problem-based (PBL) methodologies. Therefore, STEAM education approach can engage students in problems of real-life context, which cater to the needs and demands of the modern economy. Moreover, the science, technology, engineering, arts and mathematics curriculum received international reorganizations and appreciations within short span of time (Christenson, 2011).

Similarly, the curriculum in which Arts and design infused into science, technology, engineering and mathematics education was accepted by the National Arts Education Association (Liao, 2016). Thus, the integration of Arts into local and traditional curricula, was the main objective of the STEAM curriculum. Which require the renewal of research policy, and to enhancement of creativity and innovation among students (Rolling, 2016). In addition, because of Every Student Succeeds Act (ESSA) in 2015 STEAM education has been implemented in America in different ways (Liao, 2016).

Furthermore, every activity of STEAM curriculum revolves around the child. Therefore, make it a child centered approach. In addition to, following teaching methodologies are required for the successful implementations of STEAM curriculum these methodologies include; project based, problem-based, activity-based, and inquiry-based learning. It was emphasized by Herro and

Quigley (2016) critical thinking and creative skills enhanced in students with respect to authentic real-life problems by applying problem-based learning (PBL) and inquiry-based learning (IBL). In this way, students work in a collaborative manner and search out the solutions to complex problems through the integration of Arts in STEM disciplines (Hashmi & Surani, 2024). Moreover, the teacher role in STEAM education is facilitator rather than knowledge distributer.

Research Objectives

1. To analyse the content of science, technology, engineering, arts and mathematics STEAM curriculum.
2. To investigates the challenges regarding implementations of STEAM curriculum.
3. To identify the strengths and areas of improvement of the science, technology, engineering, arts and mathematics STEAM curriculum.

Research Questions

1. How effectively do STEAM curriculum integrate the five disciplines of science, technology, engineering, arts, and mathematics?
2. To what extent do the STEAM curriculum promote transdisciplinary learning and the application of knowledge to real-life contexts?
3. How creativity, critical thinking, and problem-solving skills reflected and encouraged in the content and activities of the STEAM curriculum?
4. What are the major strengths, gaps, and challenges identified in the STEAM curriculum?

Research Design and Sampling:

Research Design

This study employed a qualitative content analysis design to explore how effectively the Robotmea's Pakistan STEAM curriculum integrateas the five disciplines of STEAM education. Qualitative content analysis allows for the systematic, objective, and in-depth examination of textual material to identify patterns, themes, and meanings within the content (Schreier, 2012; Elo & Kyngäs, 2008). This approach is particularly appropriate for curriculum studies, as it provides insights into the structure, emphasis, and pedagogical orientation of instructional materials (Krippendorff, 2019).

In the context of this study, qualitative content analysis was used to examine how the Robotmea's Pakistan STEAM curriculum textbooks promote transdisciplinary learning, creativity, critical thinking, and real-world problem-solving. Following the recommendations of Mayring (2019) and Bengtsson (2016), the analysis involved systematic coding, categorization, and interpretation to derive meaningful themes which were associated with the study's objectives. The focus remained on uncovering the implicit and explicit pedagogical intentions of the STEAM curriculum as reflected in the textbook content.

Sample of the Study and Sampling Technique

Purposive sampling is a non probability sampling technique in which the participants are deliberately selected by the researcher based on specific characteristics or qualities that are aligned with the objectives of the study (Creswell & Poth, 2018). However, in purposive sampling, the researcher selects individuals who are believed to be knowledgeable and informative Gay (2012). Therefore, purposive sampling technique was adopted, as it enables researchers to deliberately select materials or participants that are most relevant to the research objectives (Patton, 2015). The sample comprised of total thirty chapters drawn from Robotmea's Pakistan STEAM curriculum textbooks for primary-level students. These chapters were selected based on their coverage of key STEAM domains, inclusion of interdisciplinary activities, and representation of different grade levels to ensure comprehensive coverage of the curriculum. Furthermore, the sampling ensured that the content analysed were representative of the overall pedagogical philosophy and instructional design of the STEAM curriculum textbooks developed by Robotmea Pakistan.

Validity, Pilot Testing, and Reliability of Content Analysis

Validity, pilot testing and reliability of content analysis of STEAM curriculum carried out in following way.

Validity

Content validity of STEAM curriculum was carried out by the experts of relevant field. However, their main focus was on the relevance and clarity of the coding, categories and themes emerged. Thus, according to their observations CVI (Content Validity Index) was calculated. Therefore, on the basis of Average Relevance Rating = 3.6/4. CVI = 0.90 content validity was found excellent.

Pilot Testing

In order to assess practicality and clarity of STEAM curriculum content analysis. Pilot testing was carried out, with ten members including STEAM teachers and curriculum experts aware with STEAM curricula. It was believed by 90% of experts that coding scheme, categories and themes were relevant. However, Slight changes were made which were based on feedback provided by the experts including rewording of few categories.

Reliability

Reliability of the research tool is defined as the process that indicates the consistency and authenticity of research tool (Cypress, 2017). That means same results obtained when data passed through different reliability tests occurred at different times with different individuals. Moreover, four standards of reliability such as transferability, credibility, conformability and dependability was recognized by Creswell (2014), Guba and Lincoln (1994). However, in order to check the reliability of the STEAM curriculum, intercoder and inter-rater reliability have been applied. The procedure is given below.

The Inter-Rater Reliability

In this type of reliability same section of content from each unit (Junior 1- 3) analyzed by two raters. Same coding framework was utilized by both raters, and then the texts were categorized and themes identified by them. Thus, level of agreement between two raters were calculated by the Cohen's kappa value. However, the kappa value equal to 0.80 is the indication of strong agreement between the two raters.

Table 1

Shows the Cohen's kappa value

Kappa Value	Agreement Level	Percentage of reliable data
.40–.59	Feeble	15–35%
.60–.79	Modest	35–63%
.80–.90	Robust	64–81%
Above.90	Perfect	82–100%

The Intercoder-Reliability

After two weeks of the same content analysis framework the intercoder reliability was carried by same raters to check the consistency and reliability in categorization, coding, and themes. Additionally, the co-relation of coding scheme from the two analyses was calculated. Strong reliability was observed with Correlation (r) of 0.87 that indicates high consistency.

Data collection

Data of present research study collected from Robotmea's Pakistan STEAM curriculum textbooks designed for their addition model of primary school level students in Pakistan. A total of thirty chapters from grades 1 to 3 textbooks were selected using purposive sampling technique to ensure adequate representation of different STEAM domains and pedagogical practices (Creswell & Poth, 2018). Each selected chapter served as a unit of analysis, including textual content, visuals, projects, activities, and reflection exercises. The contents of curriculum were systematically reviewed and documented by the researcher using a structured data extraction template developed, which was based on previous STEAM curriculum content analysis frameworks (Cheng, 2023; Gresnigt, 2014).

Data Analysis

The study utilized a qualitative content analysis approach, following the procedures outlined by Schreier (2012) and Mayring (2019). This method allowed the researcher to systematically describe the meaning of the textual content by classifying it into categories based on thematic relevance.

The content analysis proceeded in three stages, which are preparation, organization, and reporting (Elo et al., 2014). The preparation phase involves the researcher becoming deeply familiar with the data through repeated readings to capture the context and underlying pedagogical intent. In the organization phase, a deductive coding framework was developed based on the study objectives and STEAM education literature (Chung, 2021; Li, 2020). Codes were grouped into broader categories such as disciplinary integration, creative engagement, critical thinking development, and real-world applications. As patterns and relationships emerged, categories were refined into overarching themes that reflected how the Robotmea's Pakistan curriculum textbooks embodied the principles of STEAM education. The reporting phase involved presenting these themes with supporting evidence.

Table2

Shows the Conceptual Content Analysis "Junior 1, 2, 3".

Class Level	Chapter Title	Codes	Categories	Themes
Junior 1	Gadget Arm	1.1.2: Real-life Applications	Cognitive Engagement	Understanding mechanical movement
		2.1.1: Practical Activities	Skill Development	Hands-on building and operational skills
		3.1.1: Integration of Disciplines	Creative Expression	Storytelling with technology
		4.1.1: Real-life Experiences	Social Relevance	Application of mechanical concepts
Junior 1	Dancing Frog	1.1.1: Innovative Solutions	Cognitive Engagement	Life cycles and biological functions
		2.1.2: Experimentation	Skill Development	Building and operating a mechanical frog
		3.1.2: Connections between STEAM	Cultural Relevance	Integration of cultural narratives
		5.1.2: Inquiry-based Learning	Creative Expression	Designing and storytelling
Junior 1	Eagle Robot	1.1.2: Real-life Applications	Cognitive Engagement	Concepts of flying and motion in the air
		2.1.1: Practical Activities	Skill Development	Building and operating eagle robot
		3.1.1: Integration of Disciplines	Creative Expression	Combining science with design
Junior 1	Helicopter	1.1.2: Real-life Applications	Cognitive Engagement	Concepts of propulsion and motion
		2.1.1: Practical Activities	Skill Development	Building and operating a robotic helicopter
		3.1.1: Integration of Disciplines	Creative Expression	Combining science with design
Junior 1	Rubber band gun	1.1.2: Real-life Applications	Cognitive Engagement	Concepts of propulsion and motion
		2.1.1: Practical Activities	Skill Development	Building and testing a balloon-powered car
		3.1.1: Integration of Disciplines	Creative Expression	Combining science with design

Class Level	Chapter Title	Codes	Categories	Themes
Junior 2	Racing Car	1.1.2: Real-life Applications	Cognitive Engagement	Principles of force and direction
		2.1.1: Practical Activities	Skill Development	Constructing and programming a racing car
		5.1.1: Project-based Learning	Creative Expression	Designing race tracks and problem-solving
		4.1.1: Real-life Experiences	Social Relevance	Discussion of transportation technology
Junior 2	Swing Carousel	1.1.3: Critical Analysis	Cognitive Engagement	Centrifugal force
		2.1.1: Practical Activities	Skill Development	Building and operating the carousel
		3.1.1: Integration of Disciplines	Creative Expression	Design of the swing carousel
		4.1.2: Logical Progression	Content Relevance and Arrangement	Logical progression of concepts
Junior 2	human Bot	1.1.3: Critical Analysis	Cognitive Engagement	Principles of leg motion
		2.1.2: Experimentation	Skill Development	Conducting experiments with Human Bot.
		3.1.2: Connections between STEAM	Creative Expression	Integrating math and science in experiments
Junior 2	Crane Robot	1.1.3: Critical Analysis	Cognitive Engagement	Principles and types of pulleys.
		2.1.2: Experimentation	Skill Development	Conducting experiments with crane Robots.
		3.1.2: Connections between STEAM	Creative Expression	Integrating math and science in experiments
Junior 2	Bike Robot	1.1.3: Critical Analysis	Cognitive Engagement	Principles of balance in a bicycle
		2.1.2: Experimentation	Skill Development	Conducting experiments with Bike Robot
		3.1.2: Connections between STEAM	Creative Expression	Integrating math and science in experiments
Junior 3	Tank Robot	1.1.1: Innovative Solutions	Cognitive Engagement	Principles of friction and mobility
		2.1.2: Experimentation	Skill Development	Building and operating a tank robot
		4.1.1: Real-life Experiences	Social Relevance	Tank robot tracks in various industries
		3.1.2: Connections between STEAM	Creative Expression	Designing tank robots with unique features
Junior 3	Grab Robot	1.1.1: Innovative Solutions	Cognitive Engagement	Principles of grabbing things and mobility
		2.1.2: Experimentation	Skill Development	Building and operating a Grab robot
		4.1.1: Real-life Experiences	Social Relevance	Grab robot tracks in various industries
		3.1.2: Connections between STEAM	Creative Expression	Designing Grab robots with unique features

Class Level	Chapter Title	Codes	Categories	Themes
Junior 3	Soldier Robot	1.1.1: Innovative Solutions	Cognitive Engagement	Principles of servo motor and mobility
		2.1.2: Experimentation	Skill Development	Building and operating a soldier robot
		4.1.1: Real-life Experiences	Social Relevance	Soldier robot tracks in various industries
		3.1.2: Connections between STEAM	Creative Expression	Designing soldier robots with unique features
Junior 3	Avoider Bot	1.1.3: Critical Analysis	Cognitive Engagement	Understanding sensory mechanisms
		2.1.1: Practical Activities	Skill Development	Building and programming a sensor-based robot
		5.1.1: Project-based Learning	Creative Expression	Designing a robot for specific tasks
		4.1.1: Real-life Experiences	Social Relevance	Application of sensors in robotics
Junior 3	Banner Robot	1.1.1: Innovative Solutions	Cognitive Engagement	Kinds of light
		2.1.1: Practical Activities	Skill Development	Building and operating the banner robot
		3.1.1: Integration of Disciplines	Creative Expression	Find the P.R. method
		6.1.1: Formative Assessment	Assessment and Evaluation	Classifying kinds of light

Findings:

Strengths of the STEAM curriculum

The following are important strengths of the STEAM curriculum.

Cognitive Engagement of Students

The STEAM curriculum focused on the development of intellectual abilities in students. Therefore, every chapter of the curriculum textbooks of grades I, II, and III helps in cognitive engagement of students by starting the learning process with relevant examples. This results in catching the student's attention and improving their concentration level by linking it with their previous knowledge. In addition to this, by using this method STEAM curriculum not only makes the content approachable to students, but it also helps them to reflect on their learning and use new concepts. Thus, by relating the learning to real world scenario, students are involved enthusiastically in the learning process.

Scientific Knowledge

Another noteworthy strength of the science, technology, engineering, arts, and mathematics STEAM curriculum is its ability to effectively present important scientific principles in a concise and clear way with relevant real-life examples. Furthermore, the scientific concepts like elasticity, electricity, sensor technology, and centrifugal force were organized and presented in a way that helps to boost students' understanding of scientific concepts. The arrangement of content from easy to difficult play an important role in developing deep learning in students.

Constructive Learning

Involvement of students in practical hands-on activities is a valuable strength of the STEAM curriculum. Therefore, by building and operating their models of swing carousels, banner robots, and rubber band gun the STEAM curriculum inculcates hands-on learning skills in students. As a result, students are involved in synthesizing knowledge by joining different elements in order to create functioning models of real-life scenarios, which helps them to improve their deep learning by proper understanding of the material through hands on learning process.

Practical Application

Every chapter of the STEAM curriculum design is designed in a way that connects and relates theory with practice. This, in turn, permits students to reflect on their learning and observe its significance by relating the facts from real-life situations. Moreover, by focusing on real-life scenarios, students understand the importance of scientific laws and principles. Additionally, this encourages them to think in a critical way about the real-life examples and the various technologies they utilize in their learning.

Self-Assessment and Reflective Evaluation

Another important strength of the STEAM curriculum is the self-assessment and reflective evaluation. Which helps students to reflect on their learning that leads to auto-assessment or self-assessment of their learning. Likewise, those activities included in the curriculum encourage students to categorize, investigate, and create deep involvement and better understanding of concepts. Therefore, these reflective practices develop metacognitive skills that help students to become more aware of their learning.

Areas for Improvement in STEAM Curriculum

Despite the fact that the STEAM curriculum establishes a powerful basis by engaging students through different activities in STEAM) disciplines. However, there are several areas identified in the STEAM curriculum where improvements could be made. These improvement areas are listed below.

Integration through Interdisciplinary Connections

The STEAM curriculum can provide a more holistic learning experience by integrating the STEAM disciplines in a way that blurs the boundaries between the disciplines. Moreover, students can understand better through the systematic integration of science, technology, engineering, arts, and mathematics. Furthermore, they learn how to apply knowledge from STEAM subjects in a holistic way to solve real-life problems.

Enhancement of Collaborative Learning

Inculcation of activities that promote collaboration among students during group projects can improve the learning of students through active engagement with their peers. In addition to working together in groups in a collaborative manner can help students to share with each other their perspectives; in this way, they can learn difficult concepts from each other that also leads to the development of their oratory and teamwork skills. Therefore, this makes them better candidates for the future job market.

Inculcations of More Real-Life Activities

Incorporation of more activities from the real world in the STEAM curriculum can help students to improve their learning by active engagement in real-life situations.

Formative Assessment Strategies

Students' learning and understanding of concepts can be tracked in a more practical way by the Implementation of formative assessment strategies in the STEAM curriculum. These assessments for learning strategies can lead to the provision of instant feedback, which in turn allows teachers to modify their teaching methodologies according to students' needs.

Conclusions

To sum up, a comprehensive and effective framework for the active and meaningful involvement of students in the learning process is provided by the STEAM curriculum. Furthermore, the strength of the STEAM curriculum is grounded in its capability of connecting theory with practice by integrating STEAM disciplines in a meaningful way. Moreover, this alignment leads to the development of critical thinking, communication, creativity, and collaboration skills among students. However, by addressing areas identified for improvement, the STEAM curriculum can continue to develop by preserving the fact that students are not only knowledge adapters, but they are also knowledge creators. They are equipped with those skills that are necessary for their survival in a day-to-day changing and increasingly complex technological world. In brief, the major goals of developing the creativity, communication, and collaboration skills in future generations are achieved by the STEAM curriculum in a progressive manner.

Challenges during Implementation of STEAM Curriculum

During implementation of the STEAM curriculum following challenges are faced by teachers, curriculum developers, and policy maker these challenges includes: limited manpower and material resources, community awareness, teachers' professional development, teachers' attitude about STEAM education approach, time constraints, availability of trained STEAM teachers, etc.

Recommendations:

Teacher's Training

Teachers should be trained in STEAM education by participating in both professional development and continuous professional development training. Furthermore, training of teachers in STEAM education is very important because after getting training, it would be easy for them to apply difficult STEAM curriculum concepts in an easy way and engage students in STEAM activities in a more meaningful manner in the classroom and STEAM labs.

Allocation of Man and Material Resources

Allocation of suitable man and material resources required for the implementation of the STEAM) curriculum. These resources include trained STEAM teachers, STEAM labs, STEAM robotics kits, internet, electricity, and technological resources. These should be made available for the effective implementation of the STEAM curriculum with its true spirit and ideology.

Awareness of Community

Most of the people in the community are unaware of the STEAM curriculum and its proper utilization. Therefore, it is important to make them aware through seminars, STEAM exhibitions, and orientation sessions.

Suggestions for Future Researchers

Future research can be carried out with diverse concepts based on different research designs, different variables, different data analysis tools, and different stakeholders. To investigate the long-term effect of the STEAM curriculum, longitudinal studies can be conducted based on several years of investigation and research on the STEAM education approach. Moreover, a causal comparative study can be conducted by comparing the STEAM) curriculum with the traditional curriculum. Furthermore, a research study can be carried out on STEAM robotic kits, STEAM labs, STEAM maker spaces, and the role of AI and digital media in the implementation of STEAM education.

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