



STEM competencies and innovation readiness among high school students: A study in Atal Tinkering Labs

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Abstract

Learning STEM skills and how to be innovative is getting more important in schools today. Atal Tinkering Labs (ATLs) give students a chance to do experiments, solve problems, think about design, and learn with technology. This study observed at the STEM skills and how ready high school students who use ATLs are for innovation. We studied 200 high school students. A descriptive survey research design was adopted to examine students' competencies related to their skills in science thinking, using technology, solving problems, being creative, working with others, and their readiness for innovation. We collected data with a survey we created for this study. We used basic statistics like averages and standard deviations to see how students were doing overall in STEM skills and innovation readiness. We hope this study helps us understand how ready students are to learn in innovation-focused STEM environments and find areas where they need more help. The results could help make STEM education using ATLs better in schools.

Keywords: Atal Tinkering Labs, STEM education, STEM competencies, innovation readiness, high school students, creativity, problem-solving

Introduction

STEM education is becoming more important because it helps students learn to solve problems, think creatively and critically, work with others, and use what they learn (Bybee, 2013; Kelley & Knowles, 2016) ^[2, 4]. Today's STEM education is more than just studying subjects separately. It's about combining knowledge from different areas to understand and solve real-world problems (Kelley & Knowles, 2016; National Research Council, 2012; Aguilera *et al.*, 2021) ^[4, 5, 13].

In schools, students should have chances to do more than just read textbooks. They need to try experiments, design things, build them, test them, and make them better. These kinds of activities help students develop the skills needed for innovation and solving technical problems (National Research Council, 2012; English, 2016) ^[3, 5].

The Atal Tinkering Lab (ATL) initiative provides a learning environment in schools which is innovation-oriented where students can tinker with technology and develop prototypes and explore solutions to real world problems (Kwon & Lee, 2025) ^[14]. The ATL environment is therefore of particular relevance to STEM education as it promotes hands-on and experiential learning through activities that incorporate design thinking, electronics, mechanics, 3D printing, computational thinking and prototyping (Atal Innovation Mission [AIM], 2024, 2025) ^[1, 9]. Recent ATL guidance also suggests structured, experiential educational experiences that permit students to move from basic STEM concepts to more intricate real-world applications and solution-building (AIM, 2024).

However, the presence of an innovation laboratory does not necessarily imply the development of STEM competencies of students (Muneer *et al.*, 2026) ^[15]. The assessment of ATLs has provided evidence of the fact that schools have reported improvements in areas like scientific temper, STEM achievement, 21st-century skills and students' engagement with science and technology. However, the reported outcomes also point to the importance of looking at what students actually develop through their participation in ATL activities (NITI Aayog, 2025). Thus, it is important to look at the competencies and readiness of students who participate in such learning environments. Knowledge of students' current levels of STEM competencies and innovation readiness can provide useful information for teachers, schools and educational planners in designing and improving STEM and innovation-oriented learning experiences.

Need and Significance of the Study

The rapid development of science and technology has changed the knowledge, skills and competencies necessary for students to successfully participate in modern society. As a consequence, the importance of STEM education as an approach to solve complex and authentic problems by combining scientific knowledge, technological understanding, engineering design and mathematical reasoning has increased. STEM learning can also foster problem-solving, creativity, critical thinking, collaboration, communication and the use of knowledge in unfamiliar situations (UNESCO, 2023; OECD, 2023).

In India, the focus on innovation and experiential learning has been bolstered through initiatives like the Atal Innovation Mission (AIM) and Atal Tinkering Labs (ATLs). ATLs provide opportunities for school students to work with tools, technologies and activities related to design thinking, experimentation, prototyping and problem solving (AIM, 2024). The ATL framework focuses on experiential and hands-on learning through domains such as robotics, electronics, 3D printing, Internet of Things and other emerging technologies (AIM, 2024).

However, the mere existence of an innovation laboratory does not imply the formation of students' STEM competencies. The effectiveness of these learning environments depends on how students engage with the resources and learning experiences available. Recent evidence on assessment of ATLs has reported on outcomes related to students' STEM achievement, scientific temper and 21st century skills which emphasizes the necessity of examining actual competencies developed through participation in ATL activities (NITI Aayog, 2024 ^[1]; NITI Aayog, 2025).

STEM competencies are important because students need to apply scientific concepts, technological knowledge, engineering processes and mathematical reasoning to real problems. Similarly, innovation readiness reflects students' readiness to identify problems, generate ideas, experiment to test possible solutions, work together with others and improve their ideas through iterative processes (OECD, 2023; UNESCO, 2023; Zhan *et al.*, 2024) ^[19]. Assessment of these dimensions thus can contribute to a more holistic understanding of students' readiness to engage in STEM and innovation-oriented learning (National Research Council, 2012) ^[5].

The study is particularly significant at the high school level, as this stage is important for developing higher-order thinking, academic interests and future educational and career aspirations. Providing students with opportunities for authentic STEM experiences may support the development of skills required for further education and participation in a technology-oriented society (UNESCO, 2023; OECD, 2023). Therefore, examining the existing level of STEM competencies and innovation readiness among high school students participating in ATLs is necessary.

The findings of the study may be useful to teachers in designing appropriate STEM and innovation-based learning activities, to schools in improving the effective utilization of ATL facilities, and to educational planners and policymakers in strengthening innovation-oriented STEM programmes (AIM, 2024; NITI Aayog, 2024) ^[1]. The study may also provide empirical evidence regarding the relationship between students' STEM competencies and their readiness to engage in innovation processes.

Thus, the present study, entitled "STEM Competencies and Innovation Readiness among High School Students: A Study in Atal Tinkering Labs," is significant because it seeks to examine the competencies and innovation readiness

of students within an ATL-based learning environment and provide evidence that can contribute to the improvement of STEM and innovation-oriented education in schools.

Objectives of the Study

The study has the following objectives:

1. To assess the level of STEM competencies among high school students participating in Atal Tinkering Labs.
2. To assess the level of innovation readiness among high school students participating in Atal Tinkering Labs.
3. To examine the dimensions of STEM competencies among high school students.
4. To examine the dimensions of innovation readiness among high school students.
5. To find out the significant relationship between STEM competencies and innovation readiness among high school students.

Hypotheses of the study

1. There is no significant relationship between STEM competencies and innovation readiness among high school students participating in Atal Tinkering Labs.

Method Adopted in this Study

The purpose of the study is to find out the STEM Competencies and Innovation Readiness among High School Students: A Study in Atal Tinkering Labs. Based on the nature of the problem the investigator had used survey method.

Tools Selected for the Study

A self-made tool was utilised to gather information on school students scores on the STEM Competency Scale and Innovation Readiness Scale. The school students asked to respond on the scale, which was then developed and distributed.

Description of the Research Tool

Tool 1: STEM Competency Scale

The research tool developed by the investigator to assess the STEM Competency Scale. It has 4-dimension such as science, Technology, Engineering and Mathematics. It contains 20 items, and each and every item is a closed type. Each dimension consists of five items. In this tool, the investigator has used five-point scales for the analysis.

Tool 2: Innovation Readiness Scale

The research tool developed by the investigator to assess the innovation Readiness Scale. It has 7-dimension such as Creativity, Critical Thinking, Problem -Solving, Collaboration, Idea generation, Persistence and Willingness to experiment. It contains 28 items, and each and every item of the research tool is of a closed-type nature. Each dimension consists of three items. The investigator has used Likert five-point scales for the analysis.

Population: The population is defined as well defined set of people living with common characteristics. The population of the present study is constituted of the High school students who were from Government and Government Aided School in Sivagangai districts of Tamil Nadu.

Sample and Sampling Technique

The investigator selected 200 samples from the population for this present study from in and around Sivagangai, districts. The investigator used the simple random sampling technique for this study.

Administration of the Tool

After finalising the tool, the investigator makes a personal visit to the colleges selected for the data collection. The investigator met the head of the institutions and sought permission. The investigator also gets the help of the concerned teachers. The personal data from the STEM Competency Scale and Innovation Readiness Scale tool were administered to randomly selected High school students. The students were instructed clearly and the responses were valued by the investigator with the help of the scoring key.

Statistical Techniques

The researcher employed the following statistical techniques to analyse and interpret the data, depending on the type of study hypothesis. Statistical techniques such as Mean, Standard Deviation, Percentage Analysis and Multiple Correlation Analysis were employed to analyse the data.

Data Analysis

The SPSS tool was used to do statistical analysis on the acquired data, and the results may meet the criteria for the study's goals.

Percentage Analysis

Level of STEM competencies among high school students participating in Atal Tinkering Labs

Table 1: Level of STEM competencies in Atal Tinkering Labs

Level	Low		Moderate		High	
	N	%	N	%	N	%
level of innovation readiness	45	22.5	98	49	57	28.5

Interpretation

The table shows the level of innovation readiness among 200 high school students. 45 students (22.5%) have a low level, 98 students (49%) have a moderate level, and 57 students (28.5%) have a high level of innovation readiness. The results show that most students (49%) have a moderate level of innovation readiness, followed by 28.5% with a high level and 22.5% with a low level. This indicates that most students have a moderate level of readiness and need more opportunities to improve their creativity, problem-solving, experimentation and innovation skills through ATL activities.

Table 2: The level of innovation readiness among high school students participating in Atal Tinkering Labs

Level	Low		Moderate		High	
	N	%	N	%	N	%
Level of STEM competencies	42	21	109	54.5	49	24.5

Interpretation

The table shows the level of STEM competencies among 200 high school students. 42 students (21%) have a low level, 109 students (54.5%) have a moderate level, and 49 students (24.5%) have a high level of STEM competencies. The results show that most students (54.5%) have a moderate level of STEM competencies. This is followed by 24.5% of students with a high level and 21% with a low level. The findings indicate that students have a moderate level of STEM competencies and need more opportunities for hands-on activities, experimentation, problem-solving and practical STEM learning.

Table 3: The Dimensions of STEM Competencies

Variable	N	Mean	Std. Deviation
Science	200	62.65	17.320
Technology	200	62.55	20.025
Engineering	200	62.05	20.455
Mathematics	200	62.00	20.447

Interpretation

The table shows the mean and standard deviation of students' competencies in Science, Technology, Engineering and Mathematics among 200 students.

The mean scores are 62.65 for science, 62.55 for Technology, 62.05 for Engineering, and 62.00 for Mathematics. Science has the highest mean score, while Mathematics has the lowest. The standard deviation ranges from 17.320 to 20.455, indicating some variation in students' competency scores.

Overall, the results show that the students' competency levels across the four STEM areas are fairly similar, with science showing a slightly higher mean score than the other areas.

Table 4: The Dimensions of Innovation Readiness

Variable	N	Mean	Std. Deviation
Creativity	200	61.20	20.510
critical Thinking	200	72.40	23.258
Problem-Solving	200	69.60	22.945
Collaboration	200	60.00	19.231
Idea generation	200	71.20	22.917
Persistence	200	64.80	18.834
Willingness to experiment	200	74.40	24.074

Interpretation

The table shows the innovation readiness scores of 200 students. Willingness to experiment has the highest mean score (74.40), followed by critical thinking (72.40) and idea generation (71.20). Collaboration has the lowest mean score (60.00), followed by creativity (61.20).

Overall, students show better performance in experimenting, critical thinking and generating ideas, while they need more support in creativity and collaboration.

Table 5: Significant Relationship between STEM Competencies and Innovation Readiness among High School Students Participating in Atal Tinkering Labs.

Correlations													
Variable		Science	Technology	Engineering	Mathematics	Creativity	critical	Thinking	Problem-Solving	Collaboration	Idea generation	persistence	Willingness
Science	Pearson Correlation	1	.619 **	.224 **	.709 **	.512 *	.401 *	.816 **	.073 **	.003	.264 **	.173 *	.235 **
	Sig. (2-tailed)		.000	.001	.000	.001	.001	.000	.000	.966	.000	.014	.001
	N	200	200	200	200	200	200	200	200	200	200	200	200
Technology	Pearson Correlation	.619 **	1	.139 *	.213 **	.617 **	.122	.029	.002	.304 **	.242 **	.083 **	.279 **
	Sig. (2-tailed)	.000		.049	.003	.000	.086	.688	.976	.000	.001	.000	.000
	N	200	200	200	200	200	200	200	200	200	200	200	200
Engineering	Pearson Correlation	.224 **	.139 *	1	.121	.613 *	.205 *	.152 *	.200 **	.804 **	.109	.191 **	.601 **
	Sig. (2-tailed)	.001	.049		.088	.001	.004	.031	.005	.000	.123	.007	.000
	N	200	200	200	200	200	200	200	200	200	200	200	200
Mathematics	Pearson Correlation	.709 **	.213 **	.121	1	.284 **	.806 **	.288 **	.272 **	.194 **	.218 **	.150 *	-.042
	Sig. (2-tailed)	.000	.003	.088		.000	.000	.000	.000	.006	.002	.034	.550
	N	200	200	200	200	200	200	200	200	200	200	200	200
Creativity	Pearson Correlation	.512 *	.617 **	.613 *	.284 **	1	.339 **	-.042	-.101	.581 **	.536 **	-.005	.418 **
	Sig. (2-tailed)	.001	.000	.001	.000		.000	.554	.153	.000	.000	.949	.000
	N	200	200	200	200	200	200	200	200	200	200	200	200
Critical	Pearson Correlation	.401 *	.122	.205 **	.806 **	.339 **	1	-.047	.217 **	.333 **	.243 **	.249 **	.306 **
	Sig. (2-tailed)	.001	.086	.004	.000	.000		.509	.002	.000	.001	.000	.000
	N	200	200	200	200	200	200	200	200	200	200	200	200
Thinking	Pearson Correlation	.816 **	.029	.152 *	.288 **	-.042	-.047	1	.464 **	.707 **	.130	.333 **	.334 **
	Sig. (2-tailed)	.000	.688	.031	.000	.554	.509		.000	.000	.066	.000	.000
	N	200	200	200	200	200	200	200	200	200	200	200	200
Problem-Solving	Pearson Correlation	.073 **	.002	.200 **	.272 **	-.101	.217 **	.464 **	1	.191 **	.206 **	.154 *	.061
	Sig. (2-tailed)	.000	.976	.005	.000	.153	.002	.000		.007	.004	.030	.388
	N	200	200	200	200	200	200	200	200	200	200	200	200
Collaboration	Pearson Correlation	.003	.304 **	.804 **	.194 **	.581 **	.333 **	.707 **	.191 **	1	.511 **	.078 **	.608 **
	Sig. (2-tailed)	.966	.000	.000	.006	.000	.000	.278	.007		.000	.000	.000
	N	200	200	200	200	200	200	200	200	200	200	200	200
Idea generation	Pearson Correlation	.264 **	.242 **	.109	.218 **	.536 **	.243 **	.130	.206 **	.511 **	1	.368 **	.163 *
	Sig. (2-tailed)	.000	.001	.123	.002	.000	.001	.066	.004	.000		.000	.021
	N	200	200	200	200	200	200	200	200	200	200	200	200
Persistence	Pearson Correlation	.173 *	.083 **	.191 **	.150 *	-.005	.249 **	.333 **	.154 *	.708 **	.368 **	1	.521 **
	Sig. (2-tailed)	.014	.000	.007	.034	.949	.000	.000	.030	.000	.000		.000
	N	200	200	200	200	200	200	200	200	200	200	200	200
Willingness	Pearson Correlation	.235 **	.279 **	.601 **	-.042	.418 **	.306 **	.334 **	.061	.608 **	.163 *	.521 **	1
	Sig. (2-tailed)	.001	.000	.000	.550	.000	.000	.000	.388	.000	.021	.000	
	N	200	200	200	200	200	200	200	200	200	200	200	200
**. Correlation is significant at the 0.01 level (2-tailed).													
*. Correlation is significant at the 0.05 level (2-tailed).													

Interpretation

The table presents the Pearson correlation coefficients between STEM competencies and innovation readiness dimensions among 200 students.

Science has a strong positive correlation with critical thinking ($r = .816$) and Mathematics has a strong positive correlation with critical thinking ($r = .806$). Engineering also shows a strong positive correlation with collaboration ($r = .804$). The results show that Science, Technology, Engineering and Mathematics are positively related to several innovation readiness dimensions.

Several other relationships are also statistically significant at the 0.01 or 0.05 level. However, some relationships are weak or not statistically significant. For example, Technology and problem-solving show a very weak correlation ($r = .002$, $p = .976$), and Mathematics and willingness to experiment show a weak negative, non-significant correlation ($r = -.042$, $p = .550$).

Overall, the findings indicate that STEM competencies are positively associated with many aspects of innovation readiness, although the strength of the relationships varies across the different dimensions.

Discussion of the Study

The present study examined the STEM competencies and innovation readiness of 200 high school students in Atal Tinkering Labs (ATLs). The findings showed that most students had a moderate level of STEM competencies (54.5%) and moderate innovation readiness (49%). The results also showed that STEM competencies were positively related to several innovation-readiness skills.

Studies supporting the findings

The present finding is supported by the Atal Innovation Mission (AIM) assessment, which reported that ATLs helped students develop innovation skills, 21st-century skills, critical thinking and problem-solving abilities.

Similarly, D'Souza (2024) ^[11] and Kelley and Knowles (2016) found that students participating in tinkering activities developed creativity, design thinking, computational thinking, problem-solving and other 21st-century skills. This supports the present finding that ATL students show development in STEM and innovation-related competencies.

The findings are also supported by Chandak and Mohare (2025), Kwon and Lee (2025) ^[9, 14], who reported that tinkering activities were associated with higher creative self-efficacy, problem-solving confidence and STEM interest among students (Ondeş, 2025) ^[16].

Further, a recent meta-analysis found that integrated STEM education can improve students' cognitive skills and problem-solving performance, supporting the positive relationship between STEM competencies and innovation-related skills found in the present study (Chen *et al.*, 2025) ^[10].

Studies showing contrasting findings

Although the present study found generally positive relationships among STEM competencies and innovation-readiness dimensions, the strength of the relationships was not the same for all variables. This is consistent with research showing that the outcomes of STEM programmes can vary depending on the type of activity, teaching strategy, duration and implementation (Govind (2026) ^[12].

A recent study on ATLs also reported some challenges. It found that while tinkering supported creativity and problem-

solving, it could sometimes divert students' attention from basic knowledge and increase teachers' workload when ATL activities were not well connected with the regular curriculum (2026) ^[12].

Thus, the present study generally agrees with earlier research that ATL and integrated STEM activities can support students' problem-solving, creativity, critical thinking and innovation skills (Pinar *et al.*, 2025) ^[17]. However, the moderate levels found in the present study suggest that simply having an ATL may not be sufficient. Regular hands-on activities, teacher support, teamwork, experimentation and proper integration of ATL activities with the school curriculum may be needed to further strengthen students' STEM competencies and innovation readiness.

Conclusion

The present study concludes that most high school students in Atal Tinkering Labs have a moderate level of STEM competencies and innovation readiness. The findings also show a positive relationship between STEM competencies and several innovation skills such as creativity, critical thinking, problem-solving, collaboration, idea generation, persistence and willingness to experiment. The study indicates that ATL activities provide useful opportunities for students to develop STEM knowledge, practical skills and innovation abilities (Yu *et al.*, 2024) ^[1]. However, more regular hands-on activities, experimentation, teamwork and problem-solving opportunities are needed to further improve students' competencies and innovation readiness. Overall, effective use of ATLs can support the development of students' STEM and innovation skills.

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