LETTERS IN BIOMATHEMATICS
An International Journal

RESEARCH ARTICLE

OPEN ACCESS

Impact of Teacher Knowledge of STEM Teaching, Curriculum Integration, Student Technological Exposure and Academic Achievement of Bio-Statistical Students: Mediating Effect of Bio-Statistical Knowledge

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ABSTRACT

Purpose: In the present competitive educational environment, it is important to look for the factors that can improve the academic achievements of biostatistical students. Therefore, the aim of the present research is to examine the effect of Teacher Knowledge of STEM Teaching, curriculum integration, and Student Technological Exposure on the academic achievement of biostatistical students. This research also explored the moderating effect of STEM self-efficacy and the mediating effect of biostatistical knowledge. Design/ method/ approach: This research is cross-sectional by research design. Data were collected from the students of biostatistics using simple random sampling. Data were gathered from 350 students of biostatistics. The collected data were analyzed using the SEM technique and the Smart PLS tool. Findings: Findings revealed that Teacher Knowledge of STEM Teaching, curriculum integration, and Student Technological Exposure have a significant positive effect on biostatistical knowledge. Moreover, biostatistical knowledge has a positive effect on academic achievement. Research confirmed the mediating effect of biostatistical knowledge and the moderating effect of STEM self-efficacy. Originality: The present research is among the limited studies that examined the mediating effect of biostatistical knowledge and the moderating effect of STEM self-efficacy.

ARTICLE HISTORY
Received November 19, 2025
Accepted March 05, 2026

KEYWORDS
Biostatistical Knowledge,
Biostatistical Students,
STEM Self-Efficacy,
Teacher Knowledge,
STEM Teaching

1. Introduction

Academic achievement is one of the vital factors of educational success and learning outcomes among the students of biostatistics (Arquilada, 2024). Academic achievement shows statistical competence, analytical skills, and the level of knowledge that is developed by the students of biostatistics during their studies. From the perspective of biostatistics education, academic achievement shows the ability of students to interpret medical and biology data in an effective manner, apply quantitative methods, and understand the theory of statistics (Nowacki et al., 2025). A high level of academic achievement among students of biostatistics is important because it shows students' readiness to perform complex analysis of data in clinical studies, epidemiology, and health research (Sakarna et al., 2025). Academic achievement plays an important role for students of biostatistics in building critical thinking skills and problem-solving abilities required for decision-making on the basis of evidence. Moreover, academic achievement motivates students of biostatistics to pursue research careers and advanced studies in medical sciences and public health (Putwain et al., 2024). Thus, it is very important for biostatistics students to improve academic achievement to strengthen their statistical competence for professional roles in data-driven and healthcare research scientific investigations.

It is very important to integrate biostatistics into biology because modern education in biology relies on data analysis and quantitative reasoning. Students easily understand the way biostatistics provides support to the concepts of biology with the help of a pedagogical framework that is data-driven. Statistics is one of the key factors in different medicine- and science-related subjects. The field of biostatistics deals with applied areas of medicine, health sciences, and biology. It is vital for healthcare providers to understand progress in the investigation of statistics so they can apply statistics in medical and health-related decisions (Sakarna et al., 2025). Thus, biostatistics plays vital role in growth of medical research.

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STEM education requires students to gain 21st-century skills. These skills enable students to find solutions to problems from different perspectives and to think creatively, critically, and systematically (Hacıoğlu, 2021). STEM education also offers practical guidance to students. The basis of STEM education is the process of problem-solving that students face on a daily basis. STEM education is important for students to develop their ability to make inventions and create products, to work together, to research and solve problems, and to pursue inquiry. Qualified STEM teachers are needed to deliver high-quality STEM education. Teachers must have knowledge about these subjects for the effectiveness of STEM courses. Moreover, teachers should have a conceptual understanding of underlying applications, definitions, and rules. Knowledge of pedagogical skills and STEM fields is vital in STEM teaching. Teachers are needed to introduce students to career-related activities, role models, and career discussions. From this perspective, students get motivated to increase their interest in the field of STEM (Tekin & San, 2023).

Curriculum integration plays a very important role in improving the learning experience of students of biostatistics (Ali & Khan, 2018). Curriculum integration is the systematic connection between different learning activities and subjects to create a coherent and meaningful educational experience (Akib et al., 2020). Curriculum integration helps biostatistical students link concepts of statistics with real-world applications in medical research, epidemiology, and health sciences. Through effective integration of the curriculum, biostatistics students are able to understand how statistical theories are applied in health-related data and in analyzing biological data. Curriculum integration enhances biostatistics students' understanding of research methodology, problem-solving abilities, and analytical skills (Sami et al., 2020). When there is effective implementation of curriculum integration, biostatistics students develop an understanding of the tools of statistics. Moreover, it also helps biostatistics students with their practical relevance in science studies. As a result, curriculum integration strengthens biostatistics students' readiness, confidence, and competence to apply biostatistics techniques in professional practice and research within the medical and health fields (Ellis, 2023).

Biostatistics students' technological exposure plays a key role in enhancing their academic development and learning experience (Kalyani, 2024). Technological exposure of biostatistics students shows access to modern digital resources, software, and technological tools used in statistical research and analysis. Technological exposure of biostatistics students is vital because different statistical techniques are performed through software such as programming tools, data analysis platforms, and statistical packages (Keane et al., 2023). Increased technological exposure of biostatistics students enables them to efficiently apply quantitative methods, interpret statistical outputs, and analyze biological datasets. Technological exposure for biostatistics students improves their problem-solving skills. It also strengthens their understanding of statistical applications in public health and healthcare research. Therefore, improving technological exposure of biostatistics students is important to enhance their professional readiness, capability, and technical competence.

STEM self-efficacy is important in contemporary educational research, specifically in learning environments of science, technology, engineering, and mathematics (STEM)(Luo et al., 2021). STEM self-efficacy is referred to as the belief of statistical students regarding their capability to successfully solve problems and perform tasks that are related to STEM disciplines. These beliefs influence biological students' performance, persistence, and engagement in STEM education. STEM self-efficacy plays a very important role in developing motivation among biological students. Students with higher levels of STEM self-efficacy show stronger academic commitment. Such students are likely to persist when biological students face academic challenges. Moreover, STEM self-efficacy is an important predictor of long-term participation, career decision-making, and academic achievement. Thus, the enhancement of STEM self-efficacy among biostatistical students is important to improve STEM learning outcomes. The aim of the present research is to explore the effect of Teacher Knowledge of STEM Teaching, curriculum integration, and Student Technological Exposure on the academic achievement of biostatistical students. Present research also explored the moderating effect of STEM self-efficacy and the mediating effect of biostatistical knowledge.

2. Literature Review

2.1 Bio-Statistical Knowledge and Academic Achievement of Bio-Statistics Students

Studies has defined academic achievement as multifactor educational outcome that shows the level to which students has achieved certain goals, typically gauged through grade point averages also known as GPA or numeric ranks (Su & Cheng, 2019). Other studies have defined the concept as the level to which students are able to achieve their academic and research goals (Al-Mekhlafi & Osman, 2022). The importance of academic achievement lies as it is the element that indicates the importance of research and academic learning, reflecting ability of students to apply and interpret empirical evidence in effective manner. Different studies discussed that academic achievement is one of the vital elements because it is considered as educational outcome. Specifically, academic achievement involves achievement of certain results in different tests and assignments. Moreover, it mostly shows the grade point average in numeric and average form. Studies mentioned that there is correlation between the attitude of students and the academic achievement, indicating that attitude

of student at the start of biostatistics course develop confidence that impacts their academic performance (Su & Cheng, 2019).

Scholars have termed biostatistics to refer to the studies to link studies of biological sciences such as biology, medicine and health to statistics. Thus, biostatistics in past studies is referred as linkage of data with biology that takes place outside the biological sciences. Some of the studies mentioned it as the linkage of science with application of different models of statistics with data collected from non-medical field (Dakhale et al., 2012). Biostatistical Knowledge is application and understanding of mathematical principles, statistical methods and different techniques for the analysis of data from public health studies, medical studies and biological studies (Ibrahim et al., 2022). It is based on research process that includes interpretation of results, analysis of data, summarization of results, data collection and design of experiments (Ruangsakul, 2025). Biostatistics is based on usage of different techniques of statistics to get some meaningful conclusion based on design experiments, and test hypothesis to human health. Biostatistics is considered as one of vital fields to create policies of public health, make discoveries, diagnose disease, and develop treatment. It is key to translating findings into refining measurement, analyzing different data sets, and actionable knowledge, thus promoting medical science.

Students get needed skills to present, interpret, analyze and collect data in effective manner with the help of biostatistics (Brearley et al., 2023). Understanding different statistical concepts such as hypothesis, regression, correlation and standard deviation testing enables students to perform better in practical work, examinations, and assignments that are research based. Students who showed strong statistical knowledge has the ability to understand different experiments and read research articles. These students also has the ability to apply appropriate statistical techniques during biological research (Candra et al., 2025). As a result, the ability of students to solve the problems improves and academic efficiency is enhanced. The academic outcomes are also strengthened because of this practical expertise. Furthermore, students are able to evaluate evidence-based studies which are important in different disciplines like public health. In presence of strong knowledge of biostatistics, the academic achievement of students is improved (Castro & Orbea, 2026; Tafwidhah et al., 2025). In other words, biostatistics knowledge has positive significant effect on academic achievement of biostatistics students (Tafwidhah et al., 2025).

So, it is hypothesised that

H1: Biostatistics knowledge has positive significant effect on academic achievement of biostatistics students

2.2 Teacher Knowledge of STEM Teaching and Bio-Statistical Knowledge

There exist close link between Statistical knowledge and STEM teaching because effective instructions regarding STEM mostly requires teachers to provide guidance to students in interpreting, analyzing and collecting data that is derived from scientific investigations (Schreiter et al., 2024). Teacher Knowledge of STEM in studies is explained as combination of expertise of strong content in Mathematics, engineering, technology and science with effective teaching skills along with understanding of the needs of learner. It is based on get expert in different subjects, the capacity to apply appropriate instructional strategies and the ability to integrate interdisciplinary concepts during STEM activities (Margot & Kettler, 2019). Teachers having sufficient Knowledge of STEM are more adaptable and confident in their methods of teaching. They have ability to introduce students to STEM related career opportunities, professional role models, and career discussion at early stages of education. Because of their pedagogical content, they are able to explain mathematical and scientific ideas in ways that are accessible and meaningful to learners (Hurley et al., 2024).

Teacher knowledge is based on understanding of student learning processes, subject expertise and pedagogical skills. All these factors affect the learning outcome of the students (Mafa-Theledi, 2024). When teachers are able to implement activities that are based on STEM and develop integration among technology and activities if classroom, students get more satisfied and engaged. Students perceive learning process as more convenient when instructional practices are efficient and clear. As a result, they reduce emotional and cognitive burden. There exists strong relationship among acceptance of technology and technology supported learning specifically in context of ease of use. When providing facilities to different conditions such as technical support, digital resources and teacher expertise, students develop positive attitude regarding attitude of STEM education. Students are encouraged to take part on inquiry based learning, collaborative projects and different experiments because of supportive learning and subjective norm that will lead to deeper understanding of different concepts (Zhao & Huang, 2025).

From this perspective, knowledge is perceived as important factor of STEM teaching, specifically in health related and biological investigations. Teachers who have statistical literacy and STEM knowledge (both) has the ability to provide guideline to students in applying statistical tools, collecting biological data and design experiments for interpretation of research findings. Past literature shows that teachers having STEM knowledge has positive influence on their knowledge about biology (Candra et al., 2025). The knowledge of teachers regarding STEM plays the foundational role for biology knowledge. Similarly, the research of Guo et al. (Guo et al., 2024) mentioned positive effect of teacher STEM knowledge on biostatistical knowledge.

H2: Teacher Knowledge of STEM Teaching has positive effect on Bio-statistical knowledge

2.3 Curriculum Integration and Bio-Statistical Knowledge

Studies has discussed curriculum integration as instructional approach in which different skills, concepts, and knowledge are combined to create interconnected and meaningful learning experiences of the students (Abu-Hijleh et al., 2025). Instead of separate teaching disciplines, this method develop connection between different subjects so that students develop ability to understand the knowledge of different fields in combination with real time problems of the world (Drake & Reid, 2018). Curriculum integration is mostly regarded as student centered that encourages students to take part in collaborations, critical thinking, and problem-based learning. Students are able to apply knowledge from different discipline in an organized manner through integrated learning that enhances the understanding of students and provide support for deeper learning outcomes (Kreijkes & Greatorex, 2024).

There exists strong correlation between curriculum integration and statistical knowledge as statistics is the base of connection between different disciplines of sciences. Statistics has very important role to play in order to facilitate integration of subjects of STEM because it is added in curricula of individual STEM. It is also key to design learning experiences of different subjects (Forawi et al., 2025). One of the basic concepts in the subject of Statistics is variation that provides a beginning point of meaningful activities in context of STEM. The introduction of statistical practices and data analysis at the level of schools enable students to understand the way different evidence is interpreted, analyzed and generated across all scientific fields. According to scholars, statistics provide support to different learning experiences by providing help to students so they can make decisions on the basis of evidence. Thus, biostatistical knowledge plays the role of bridge between data based reasoning and scientific inquiry.

Past studies support the relationship between biostatistical learning and curriculum integration. Scholars reported that integration of curriculum into biostatistics improves motivation of students and understanding towards the subject. Studies suggests that teachers must mention the importance of different subjects including biostatistics by mentioning real examples to students from the literature of medical that shed lights on the importance of different statistical methods as well (Sami et al., 2020). Teaching methodology should be problem oriented in integrated curriculum rather than technique based. Traditional teaching methods that focus on manual calculations and formulas often discouraging students. On the other hand, problem-based approaches focus on application of statistical results and their interpretation. Moreover, the usage of statistical software and computer based learning such as SPSS has the ability to male learning process more meaningful and interactive (Naqvi & Khan, 2025). By allowing students that they can focus on interpreting different results rather than doing calculations that are complex. The research skills and understanding of the students improve in this way (Bukumiric et al., 2022). Overall, integration of biostatistical knowledge in the curriculum will enhance ability of students to make informed decisions, conduct research and analyze data. The study by Bednarowska-Michaiel and Uprichard (Bednarowska-Michaiel & Uprichard, 2026) also revealed that curriculum integration has positive effect on biostatistical knowledge. So, it is hypothesized that

H3: Curriculum Integration has positive effect on Bio-statistical knowledge

2.4 Student Technological Exposure and Bio-Statistical knowledge

Technology in context of education is important to develop skills of 21st century. The workforce around the globe is relying more and more on different digital tools. Therefore, students must be proficient in using technology from their early age (Zou et al., 2025). Exposure to digital collaboration tools, coding activities and devices equipes students with problem solving and digital literacy skills that are important to be successful in technology-based society. Technology exposure is the experience, access, and familiarity that students have with different digital tools such as educational applications, software and internet at school and home (Georgopoulou et al., 2025). The main purpose is to improve academics of the students by interactive learning. As a result, students will get prepare for the future (Zhang et al., 2016).

By using different technology-related tools students are enabled to interact with concepts of statistics in practical and meaningful ways. Different types of modern technology such as data visualization platforms, simulations, online databases and statistical software allow students to examine and explore different data sets that are complex. Later, statistical procedures are applied on real time basis. With the help of these tools, students develop ability to interpret confidence intervals, perform regression analysis, test hypothesis, and visualize distribution more effectively as compared to traditional method of learning. Technology provides support to experiential and active learning where students learn by performing real time tasks. As a result of this interactive learning environment, conceptual understanding of the students of different topics of stats improves and they are able to link it with health and biological data (Yuliana et al., 2025). Studies mentioned that technological exposure helps students in learning biostatistical knowledge. Study by Xu et al. (Xu et al., 2014) examined the influence of technology on learning. They revealed that online courses, statistical software, and computers are very useful for the understanding of the concepts of biostatistics. Among different tools such as internet usage for the learning is useful for students to get information regarding statistics and biology (Abdulganie et al., 2025).

The emphasize of STEM learning environment focuses on the problem-solving skills, data analysis and integration of technology with purpose to understand phenomena of science. When students are engaged in usage of different tools of technology, they are in better position to interpret data of stats and analyse data of biology. The studies by Rusydiyah et al. (Rusydiyah et al., 2021) revealed that Student Technological Exposure has positive effect on student knowledge. Thus, it is hypothesized that

H4: Student Technological Exposure has significant positive effect on Bio-statistical knowledge

2.5 STEM Self-Efficacy as Moderator

In past studies, self-efficacy is referred as belief of an individual in her or his capacity to execute and organize the required actions in order to achieve certain goals (Yahaya et al., 2024). In settings of education, STEM self-efficacy shows confidence of students in their ability to perform the tasks related to mathematics, engineering, technology, and science (Escobar et al., 2023). These beliefs of the students are specific to tasks and are impacted by previous academic achievements, vicarious learning, social persuasion and mastery experiences. Self-efficacy plays the role of key factors that impact resilience, persistence, effort, and goal selection when encountering academic challenges (Abdolrezapour et al., 2023).

The vitality of STEM self-efficacy is discussed in a number of past studies because of its strong relationship with performance and motivation of students in disciplines of STEM. Students with high levels of self-efficacy are likely to persist when facing challenges, invest in learning activities and set challenging academic goals. On the other hand, students having low STEM self-efficacy often have doubts in their academic activities leading to reduced academic engagement. Past studies mentioned that STEM self-efficacy plays key roles to improve develop interest among students regarding studies.

In context of education, STEM self-efficacy has the ability to operate as moderator in certain paths (Dangur-Levy, 2026). As a moderating variable, STEM self-efficacy has the ability to weaken or strengthen the relationship between academic outcomes and learning experiences of the students. Students who have strong STEM self-efficacy are capable to transform educational opportunities into enhanced academic performance as students have confidence in their ability. On the other hand, students having lower STEM Self efficacy may not benefit from the learning experience. Thus, STEM self-efficacy has the ability to work as moderate variables. In past, Jimmieson (Jimmieson, 2000) also highlighted moderating role of STEM self-efficacy in their study. So, we hypothesized that

H5: STEM self-efficacy moderates between biostatistical knowledge and academic achievement of biostatistics students.

2.6 Mediation of Bio-Statistical Knowledge

Knowledge of teachers regarding STEM teaching plays very important role in improving learning outcomes of students by integration of interdisciplinary concepts and shaping the quality of instructional practices (Suherman et al., 2025). Teachers who possess good knowledge regarding teaching through STEM, are in position to explain concepts of statistics, use problem-based learning approaches and integrate technology in biostatistics classes. As a result of this instructional competence, the biostatistical knowledge of students is enhanced that enables them to interpret results, develop statistical reasoning and understand data analysis in more effective way.

Increased knowledge of biostatistics strengthens analytical abilities and conceptual clarity among students. It is very important to solve quantitative problems. Therefore, improved understanding of different statistical concepts leads to higher academic achievement of biostatistics students. The studies of Liu et al. (Liu et al., 2026) also revealed mediating effect of bio-statistical knowledge. Thus, bio-statistical knowledge has the ability to serve as mediator among teacher knowledge of STEM teaching and academic achievement of students.

H6: Bio-Statistical Knowledge mediates the relationship between Teacher Knowledge of STEM Teaching and academic achievement of Bio-Statistics students.

Meaningful learning among students is promoted through curriculum integration by connecting different concepts from different disciplines. Thus present knowledge in more organized manner (Roehrig et al., 2021). From the perspective of bio-Statistics education, integrated curriculum is the combination of statistical concepts and application of biology that enables students to understand the way different statistical tools are applied in real problems of science. As a result of this interdisciplinary approach, bio-statistical knowledge of students is enhanced and improves the ability of students to link concepts of theory with practical concepts, apply statistical methods and interpret biological data.

As stronger biological and statistical knowledge is developed among students through integration of learning experiences, their understanding of problem solving and course material improves. Enhanced understanding of application of statistics in biology contributes to improved academic achievement of students of biostatistics. Moreover, studies in past also discussed the mediating role of biostatistics knowledge in their study. Thus, bio-statistical knowledge has the

ability to function as key mediating variable. So, we assume that

7: Bio-Statistical Knowledge mediates the relationship between curriculum integration and academic achievement of Bio-Statistics students.

Technological exposure of students plays very important role in improving their learning experiences in data-oriented disciplines and quantitative disciplines. When different students are regularly exposed to analytical tools, digital data sets, and statistical software, they develop practical skills that help them to understand procedure or statistics in effective way. In context of biostatistics education, students are enabled to interpret data, visualize data and analyze data because of modern computational tools. Because of this hands-on practice technology provide strength to bio-statistical knowledge allowing students to connect theoretical concepts of statistics with application of real-world problems (Agustin et al., 2025).

With improvement of different statistical techniques, students become more capable of solving analytical problems. They develop ability to interpret data of biology in more interpret biological data. As a result, biostatistical knowledge contributes significantly to improving academic achievement of biostatistical students. The research of Melton (Melton, 2015) also highlights the mediating effect of biostatistical knowledge. So,

H8: Bio-Statistical Knowledge mediates the relationship between student technological exposure and academic achievement of Bio-Statistics students.

Figure 1 is developed on the basis of above literature showing antecedents of academic achievement of biostatistical students. This figure illustrates that biostatistical knowledge, curriculum integration, teacher knowledge of STEM teaching and student technology exposure impacts academic achievement. This figure also shows moderating role of STEM self-efficacy.

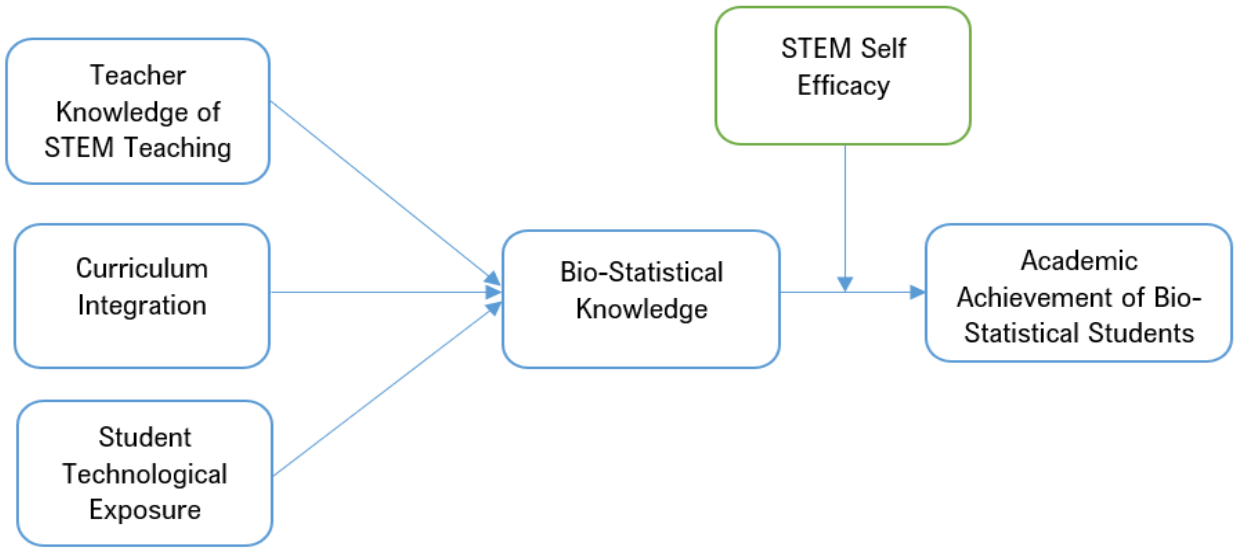

Figure 1: Framework

3. Methodology

This study is cross sectional descriptive study that was carried out through structural equation modelling. This study was carried out in the institutes teaching degree programs related to biostatistics. The population of study was biostatistics students. According to scholars, minimum sample size should be at least 200. Therefore, present study adjusted the sample size to 350 students. These students were contacted to fill in the questionnaire through self-survey method using simple random sampling.

The questionnaire of this study was developed from past literature review. The instruments of Academic Achievement of Bio-Statistical Students was developed by (Su & Cheng, 2019), the questionnaire developed by (Ibrahim et al., 2022) was used for instruments of Bio-Statistical Knowledge, items of curriculum integration was adapted from (Abu-Hijleh et al., 2025), measurement scale of Teacher Knowledge of STEM Teaching was adapted from (Wijaya et al., 2022), research questionnaire of Student Technological Exposure was developed by (Stanojevic & Rakic, 2018), and questionnaire of (Yahaya et al., 2024) used for items of STEM self-efficacy. This questionnaire developed using seven-point Likert Scale.

At this stage, questionnaire was distributed among 350 students. In total 211 questionnaires were received from the respondents which were used for further analysis. The analysis of the study was carried out using SEM technique and Smart PLS 4 tools. The analysis of the study began with SPSS for missing value analysis and demographic assessment of the respondents. Later, Smart PLS was used for further analysis.

4. Results

The initial test was carried out using SPSS. First test was missing value analysis, and it was reported that there was no missing value in the data. Then demographic characteristics of respondents were assessed through SPSS as well. Results mentioned that 58.2% of the respondents were male and 41.8% were females. Moreover, 81.27% of respondents were single and remaining mentioned their status as married. In terms of age, 51.21% respondents had the age between 18 to 30 years, 27.09%, respondents were of the age between 31 to 45 years and remaining mentioned their age of more than 45 years.

Analysis of Smart PLS started with validation of measurement model where factor loading, discriminant validity and convergent validity were examined. The convergent validity is assessed to show the correlation among the variables. For this purpose, validity of the data and AVE are examined. Validity of the data is confirmed if values of CR are more than 0.70 (Hair Jr et al., 2017). Table 1 of the study shows value of CR is more than 0.70, meeting the requirements. Moreover, AVE must also be more than 0.50, and Table 1 shows that this criterion is also fulfilled.

Table 1: CR and AVE Results

	CR	AVE
AABS	0.913	0.679
BSK	0.919	0.739
CI	0.860	0.673
SSE	0.902	0.697
STE	0.947	0.750
TKS	0.941	0.801

Later, factor loading was evaluated for which the retained items of the study must have more than 0.50 value. Table 2 shows that all factors loading figures are higher than 0.50.

Table 2: Loading

	AABS	BSK	CI	SSE	STE	TKS
AABS1	0.830					
AABS2	0.854					
AABS3	0.820					
AABS4	0.841					
AABS5	0.772					
BSK1		0.859				
BSK2		0.838				
BSK3		0.878				
BSK4		0.862				
CI1			0.849			
CI2			0.864			
CI3			0.742			
SSE1				0.876		
SSE2				0.857		
SSE3				0.884		
SSE4				0.712		
STE 3					0.863	
STE1					0.971	
STE2					0.795	
STE4					0.852	
STE5					0.862	
STE6					0.842	
TKS1						0.981
TKS2						0.857
TKS3						0.866
TKS4						0.872

In the end of measurement model, discriminant validity was examined to show the level of correlation between the variables of study. HTMT technique was used for this examination in which values must be less than 0.90 to confirm the discriminant validity. Table 3 shows the values of HTMT are less than 0.90, meeting required criteria.

Table 3: Discriminant Validity

	AABS	BSK	CI	SSE	STE	TKS
AABS						
BSK	0.799					
CI	0.385	0.409				
SSE	0.639	0.770	0.394			
STE	0.649	0.793	0.355	0.775		
TKS	0.662	0.790	0.290	0.676	0.682	

This test confirms the measurement model of the Smart PLS. Now, we moved towards the assessment of structural models to confirm the proposed hypothesis of the study. Significance of the relationship between variables were assessed through P and T values. Table 4 shows direct and moderate relationships.

Table 4: Results

	Beta	SD	T Value	P
BSK -> AABS	0.595	0.052	11.437	0.000
CI -> BSK	0.116	0.040	2.901	0.002
SSE -> AABS	0.222	0.066	3.353	0.000
SSE x BSK -> AABS	0.121	0.055	2.204	0.014
STE -> BSK	0.424	0.058	7.285	0.000
TKS -> BSK	0.416	0.049	8.429	0.000
CI -> BSK -> AABS	0.069	0.025	2.795	0.003
STE -> BSK -> AABS	0.252	0.041	6.151	0.000
TKS -> BSK -> AABS	0.247	0.037	6.625	0.000

Results mentioned in Table 4 shows that BSK has positive significant influence of AABS with t=11.437, accepting hypothesis, CI has significant positive effect on BBK with t=2.901/ Likewise, SSE has positive significant impact on AABS, having t=3.353, accepting hypothesis, STE has positive significant impact on BSK with t=7.825 supporting the hypothesis, and TKS has positive influence on BSK with t=8429. Table 4 results also demonstrate the findings of moderating results, showing that SSE moderates positively on the path of BSK and AABS, supporting this as well.

Furthermore, mediating findings are also mentioned in table 4, demonstrating that BSK mediates the between CI and AABS, with t=2.795, accepting mediation hypothesis. Similarly. BSK has significant mediating effects between STE and AABS, having t=6.151. In the end, BSK also mediates between TKS and AABS with t= 6.625. All these results are also demonstrated in Figure 2 of the study.

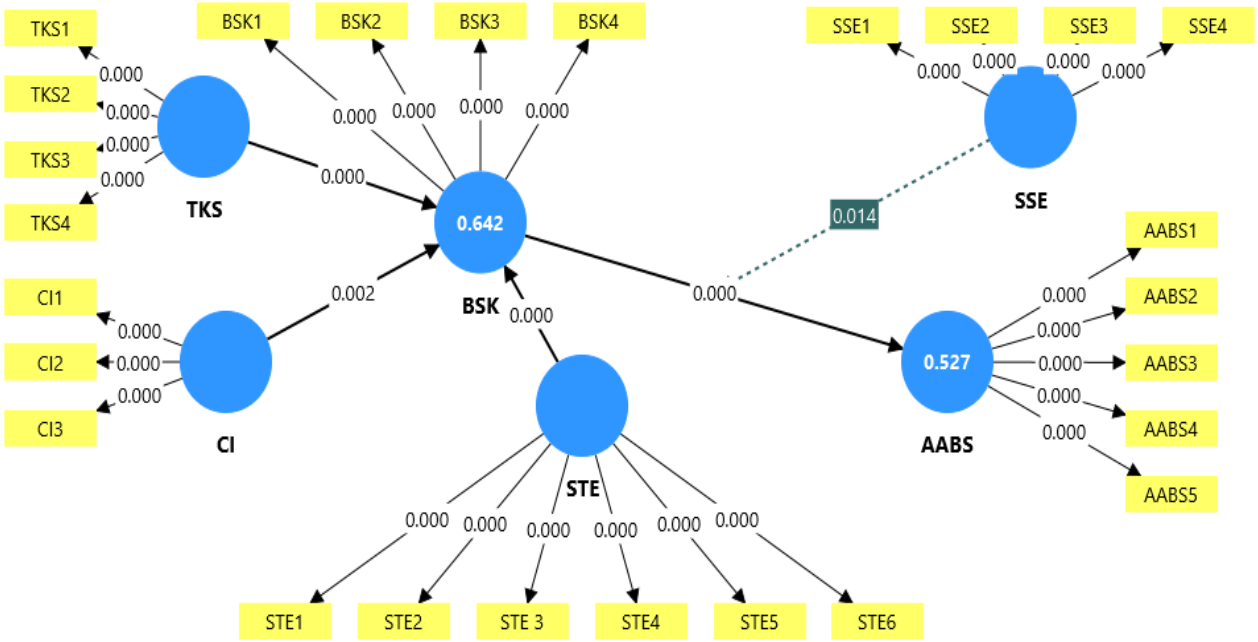

Figure 2: Structural Model

Table 5 and Figure 2 also demonstrate the R square values of mediating and dependent variables. The results show that BSK is affected 64.2% and AABS is affected 52.7% by the exogenous variables of the study.

Table 5: R Square

	R-Square
AABS	0.527
BSK	0.642

5. Discussion

The results of the study revealed that Bio-Statistical Knowledge have positive significant effect on Academic Achievement of Bio-Statistical Students among biostatistics students. The findings indicates that higher level of bio-statistical knowledge plays key role in improving academic achievement of biostatistical students. It suggests that analytical competence and conceptual understanding are important for biostatistics students. When strong bio-statistical knowledge is developed by the students of biostatistics students, they become capable of applying quantitative methods in effective manner, solving complex problems and interpreting statistical data in effective manner. This improved capability directly enhances the academic achievement of biostatistics students. Moreover, students of biostatistics are enabled to understand statistical reasoning, data analysis techniques, and research methodologies because of bio-statistical knowledge. All these mentioned components are basic factors of academic success. As bio-statistical knowledge of bio-statistics students is strengthened, their ability and confidence to perform well in coursework and assessments increase. All these will ultimately enhance the academic achievement of biostatistical students. So, promoting biostatistical knowledge among students of biostatistics is a vital strategy to improve academic achievement of biostatistical students. Similar results were revealed in study of Tafwidhah et al., (Tafwidhah et al., 2025) in past.

Results also show that Teacher Knowledge of STEM Teaching has positive effect on Bio-Statistical Knowledge of biostatistics students as discussed in study of Guo et al. (Guo et al., 2024). The possible reason for these results can be that when instructors possess strong knowledge of STEM teaching, they get ability to integrate quantitative perspectives, technological perspectives and scientific perspectives in their teaching practices. Such teacher knowledge of STEM teaching allows instructors to explain different concepts of statistics in interdisciplinary and structured manner, that helps the students to understand basics of biostatistics in more effective way. Furthermore, support is provided by effective teacher knowledge of STEM teaching regarding usage of practical examples, analytical tasks, and data interpretation activities that strengthen applied understanding and conceptual understanding. For this reason, teacher knowledge of STEM teaching develops a learning environment where students can actively engage with ideas of statistics. Therefore, they develop deeper understanding of biostatistical knowledge. Additionally, instructors having strong teacher knowledge of STEM teaching can connect statistical concepts with real life scientific problems. As a result, learning of such students become more meaningful.

Findings also indicates that curriculum integration has positive significant effect on Bio-Statistical Knowledge (Bednarowska-Michaiel & Uprichard, 2026). These findings demonstrate that curriculum integration connects different knowledge domains, enabling biostatistics students to view concepts of statistics within broader context of science. When curriculum integration is used in different learning environment, biostatistics students go through different methods of statistics along with application of biology that improves conceptual understanding of students. With the help of curriculum integration, students can easily understand data of biology with statistical reasoning. Students regularly remain exposed to integrated learning tasks. Therefore, curriculum integration improves analytical thinking of biostatistical students. Moreover, students are encouraged for interdisciplinary thinking and collaborative learning because of curriculum integration. Both these factors are important to get expert in statistical techniques and its application in research of biology. As a result, academic programs contribute significantly for the improvement and develop of biostatistical knowledge among students of biostatistics because of strong curriculum integration.

Findings also demonstrate that Student Technological Exposure has positive effect on biostatistics knowledge. These results are in line with the findings of Rusydiyah et al. (Rusydiyah et al., 2021) in past. Enhanced student technological exposure provides opportunities to students to interact with different analytical tools, digital databases, and statistical software that are used in modern practices of biostatistics. Through continuous exposure of technology to the students of biostatistics, they become more familiar with different computational methods, visualization tools, and processing techniques that improve understanding of different concepts of statistics. Furthermore, student technological exposure encourages biostatistics students to learn actively by exploring different datasets, interpret results and perform statistical calculations using platforms of technology. Conceptual clarity is strengthened and analytical capability is improved because of hands on engagement. Additionally, students can easily connect theoretical statistical knowledge with biological research because of technological exposure. With increase in student technological exposure, student gain confidence in using technological based statistical techniques that impacts overall biostatistics knowledge. Thus, promoting student exposure

to technology can significantly improve biostatistics knowledge among students.

Results of the study also supported mediating role of biostatistical knowledge between Student Technological Exposure and Academic Achievement of Bio-Statistical Students. The plausible reason for these results is that student technological exposure provides students of bio-statistics with access to different analytical tools, online datasets and statistics software that help in understanding of statistical concepts. Students slowly develop stronger biostatistical knowledge because of student technological exposure that become important to understand research methods and data analysis. Another plausible reason for this finding is that student of biostatistics practices different procedures of statistics through real datasets and simulation that strengthen biostatistics knowledge. With improvement in biostatistics knowledge, students of biostatistics become capable of completing academic tasks, solving statistical problems, and interpreting results effectively. Therefore, biostatistical knowledge plays the role of mediator between Student Technological Exposure and Academic Achievement of Bio-Statistical Students.

Findings also show that biostatistical knowledge mediates between curriculum integration and Academic Achievement of Bio-Statistical Students. These results show that curriculum integration plays important roles in improvement of academic achievement by strengthening biostatistical knowledge. With implementation of curriculum integration, different statistical concepts are taught along with research concepts and application of biology. Students of biostatistics are enabled to understand different tools of statistical in better way that slowly enhances biostatistical knowledge. Students become more capable of applying techniques of statistics and interpreting data because of stronger biostatistical knowledge. As a result, improvement in biostatistical knowledge explains the way integration of curriculum leads to improved academic achievement.

Results also showed that biostatistical knowledge mediates between teacher Knowledge of STEM Teaching and academic achievement of Bio-Statistical Students. The reason for this result is that enhanced teacher knowledge of STEM teaching improves the instruction quality that is delivered to the students of biostatistics. Teachers with effective knowledge of STEM teaching are capable of presenting concepts of Statistics through problem based learning and interdisciplinary examples. This approach helps students of biostatistics to develop deeper knowledge of biostatistics. With development of biostatistical knowledge, students also become experts in application of concepts of statistics. Thus, biostatistical knowledge mediates play the role of mediator in this relationship. In past, (Bhatti & Shodiyev, 2025) discussed the mediating effect of biostatistical knowledge in their study.

Findings also demonstrated that STEM self-efficacy moderates positive significantly between biostatistical knowledge and Academic Achievement of Bio-Statistical Students. Results indicate that positive effect of biostatistical knowledge on academic achievement is strong for students of biostatistics with enhanced STEM self-efficacy. When there is belief among the students of biostatistics to perform successfully the tasks of STEM, they apply their biostatistical knowledge with confidence to analyze data and solve complex problems. On the other hand, lower STEM self-efficacy also has the ability to limit the usage of biostatistical knowledge, minimizing the effect on academic achievement. In Literature, Melton (Melton, 2015) discussed the moderating role of STEM self-efficacy in their research.

6. Limitations and Suggestions

There are few limitations of the study that must be highlighted in this section of study. Firstly, this study is cross sectional by research design. It is proposed that future studies may use longitudinal research design for more detailed and in-depth collections of data. Secondly, data of study collected data using simple random sampling. It is proposed to use stratified sampling technique in future for data collection. Moreover, this research used STEM self-efficacy as moderator, whereas studies in future can explore technological variables as moderator in their frameworks. The study examined academic achievement of biostatistics students through proposed exogenous variables. It is proposed to apply same model in context of other fields such as Mathematics. In the end, study used Smart PLS 4 for the analysis of data. It is proposed to use PROCESS MACROS for the analysis in future similar studies.

7. Theoretical and Managerial Implications

There are a number of managerial and theoretical contributions of the study. This study is among few ones that has discussed biostatistical knowledge as mediating variable. In past, most of the studies used Knowledge in general as mediator. Moreover, STEM related variables also add to the body of knowledge by discussing their exogenous role. In literature, self-efficacy is discussed in general. This research is among limited studies that discussed STEM self-efficacy as moderator. Also, academic achievement is analyzed generally in terms of students. Whereas this research adds to the literature by analyzing it in terms of students of biostatistics. In terms managerial implications, present study highlights the importance of STEM self-efficacy to enhance academic achievements among students. These results can be used by managers to improve performance of biostatistical students. Moreover, academics and scholars can use these results in

their future studies.

8. Funding

This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [Grant Number KFU261403]'

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