

Integrating Statistical Software Usage into Biomathematics Courses: Impact on Student Research Skills

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ABSTRACT

Purpose: This study aimed to examine the impact of the use of statistical software on the research skills of biomathematics students, while exploring the mediating role of statistical self-efficacy and the moderating role of learning orientation. The research sought to understand how technological engagement, psychological confidence, and motivational orientation collectively contribute to research competence. **Method:** A quantitative, cross-sectional design was employed using data collected from 224 biomathematics students selected through stratified random sampling. Standardized scales were adopted from prior research to measure the constructs. Data were analyzed using SmartPLS 4.0, applying measurement and structural model assessments to test reliability, validity, and hypothesized relationships. **Findings:** The results revealed that the use of statistical software significantly enhances student research skills. Statistical self-efficacy was found to positively affect research performance and mediate the relationship between software use and research skills. Moreover, learning orientation significantly moderated the association between use of statistical software and research skills, strengthening this relationship among highly learning-oriented students. **Originality/Implications:** This study contributes to the literature by integrating technological, cognitive, and motivational factors within a single model. Practically, it underscores the need for research-based curricula that combine software training, self-efficacy enhancement, and reflective learning approaches to foster research competency in higher education.

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1. Introduction

Research skills have acquired a central role in academic training in modern institutions of higher learning, specifically in sciences with a strong quantitative bias, such as biomathematics, where students need to combine mathematical arguments with available empirical biological evidence (Heikkilä et al., 2023; Idek et al., 2025). Research skills are a group of diverse skills such as problem identification in research, data collection and analysis, interpretation and proper presentation of research results. Nevertheless, when the amount and difficulty of data in scientific research grow, manual approaches to statistical data processing may prove to be no longer able to assist students in acquiring such competencies (Bapanova et al., 2025). The implementation of statistical software in education has dramatically changed the approach to teaching data analysis methods, allowing students to actively and practically learn the method of data analysis, improving the conceptual knowledge base and technical skills (Rahayu et al., 2024). Software tools such as STATISTICA have gained popularity in teaching applied statistics due to their easy-to-use interface, broad analytical applications, and visual interpretation analysis which makes it easy to use by students studying biomathematics courses (Idek et al., 2025). With the ongoing focus on the research-based learning in educational institutions, the way the use of such software affects the development of the research skills of students has acquired both scholarly and practical significance.

Empirical research has shown in the past that the use of statistical software in academic education has a positive effect on the critical thinking of students and their performance in research (Sakaria et al., 2023). As an illustration, learners that are taught to apply statistical programs in a systematic way are more likely to demonstrate confidence in the choice of statistical tests, data arrangement, and the ability to interpret the output results properly (Althubaiti & Althubaiti, 2024).

Other studies have also pointed to the executions in problem-solving and information-seeking behavior through active participation of the learners in manipulation of data in software environment as opposed to learning processes that are based on lectures or textbook-based learning (Anggraeni et al., 2023). Research on STEM learning also implies that analytical activity using software helps to enhance the development of communication by allowing the clearer presentations of the findings in the form of graphs, tables, and visual summaries (Sakaria et al., 2023). Particularly, in biomathematics programs, the studies have shown that exposure to such tools as STATISTICA makes students better correlate theoretical equations with empirical biological data to provide better methodological comprehension and research confidence (Hodges et al., 2023). All these results support the educational importance of software-assisted learning in formulating research competencies.

Although there is increasing evidence to show the importance of the use of statistical software in improving the research capabilities, there are still major gaps that are evident in the current research (Leeuw & Lovric, 2025). Majority of the past research has been conducted with general scientists or social science learners but little has been done concerning the biomathematics learners since they encounter different analytical problems because of the interdisciplinary nature of their studies (Knight, 2025). Moreover, research skills have often been investigated as a unified concept in the past without investigating several distinct facets of statistical analysis, information searching, planning the methodology, problem-solving, and research communication (Hodges et al., 2023). The other gap is on the psychological factors that affect research skill development. Although such tools as STATISTICA can provide technical exposure, the degree to which students can gain benefits when exposed to technical exposure is largely dependent on their self-belief, especially statistical self-efficacy (Althubaiti & Althubaiti, 2024). However, very limited research has explored self-efficacy as a mediator factor between the use of software and development of research skills. Moreover, little studies have taken into account the effect of the learning orientation of students on their capacity to convert the confidence into the operational research performance (Silva et al., 2024). Such gaps show that a more detailed model, including a combination of cognitive and contextual elements, is necessary.

Social Cognitive Theory guides this research as it explains the process of learning as a dynamic and interaction between personal beliefs, behavioral and environmental conditions (Bandura, 2001). In this model, statistical software is an environmental instructional variable, statistical self-efficacy is a personal cognitive belief that is related to behavior and performance of the learner (Zimmerman, 2000). Learning orientation is a behavior-control component that defines the percentage of the successful application of learners to actual research assignments (Elliot & Dweck, 2013). The theoretical base justifies the anticipated relationships that the use of statistical software helps to improve research skills both directly and indirectly via self-efficacy, and that learning orientation determines the intensity of the indirect influence. On this basis, the aims of the current research can be formulated as follows: (1) to learn the effect of using statistical software on research skills in biomathematics students, (2) to test the mediation role of statistical self-efficacy in the relationship, and (3) to understand the moderating effects of learning orientation on use of statistical software and research skills. The results of this study will be used to give empirical results to enhance teaching methods in biomathematics learning.

2. Literature Review

The introduction of statistical software in higher learning has been observed as a crucial part in the development of research skills among students, especially in quantitative research interested disciplines (Obazuaye, 2025). Such statistical tools as the STATISTICA give students the experience of working with real-world data, allow them to perform sophisticated analysis and interpretation processes more accurately than working with hand calculations only (Dai et al., 2023). Researchers have observed that statistical software fosters better conceptual learning through its ability to enable students to visualize patterns, implement several analytical processes, and test hypothesis in real-time (Utomo et al., 2023). Such practical activity has proven to enhance confidence, analytical thinking and independent research abilities among students when facilitated by directed learning and problem based learning (Almutairi, 2025). In the STEM field, learning environments based on software allow knowledge to be acquired actively, but not passively, helping students to connect theoretical frameworks with practice (Heikkilä et al., 2023). These instruments also prompt the students to build systematic style of enquiry, data handling and reporting of which are central elements of professional scientific research.

The interdisciplinary nature of the field, involving mathematical models in biological phenomena, makes statistical software even more important in biomathematics education (Idek et al., 2025). This skill is necessary to interpret the biological data sets correctly, which is critical in comprehending the population dynamics, disease distribution, genetic variation, and other complex biological systems (Fiandini et al., 2024). Studies have shown that software-assisted learning would be highly beneficial to students in the field of biomathematics because mathematical models can be applied to actual biological problems (Halawa & Harefa, 2024; Limna, 2023; Rini & Aldila, 2023). Otherwise, the application of STATISTICA, in particular, enables students to model biological processes, analyze the results of experiments, and assess the accuracy of the model.

2.1 Hypothesis Development

Statistical software can be described as computer-based analytical tools that allow users to manipulate data, statistical tests, create the visualization and patterns of quantitative information (Rahayu et al., 2024). The set of research skills in students, in turn, refers to a set of competencies which facilitate the procedure of systematic inquiry, such as the capacity to develop research questions, collect and analyze information, make analytical decisions, report research results as well as apply relevant research methods (Almutairi, 2025). In the academic institution especially the science and applied mathematics courses, learning of research skills is not only restricted to theoretical learning but exposure to practical analysis is necessary (Idek et al., 2025). The statistical software should also give the learners the opportunity to interact with datasets in a systematic setting where they are given a chance to manipulate and interpret data (Sakaria et al., 2023). This integration can be used to assist students to polish their statistical reasoning, find appropriate sources of information, analyze evidence, and be accurate in presenting results. Such tools help to develop the overall competence in research by making the gap between the conceptual and practical knowledge (Althubaiti & Althubaiti, 2024).

The empirical research is always underlining the importance of introducing the use of statistical software in the educational process and learning. As an example, a study conducted demonstrated that students with systematic instruction on statistical software have a higher level of confidence when choosing and using the correct statistical method to conduct research works (Memon et al., 2021). According to other research, analysis through software enhances the skills of students in the synthesis of information in scholarly sources, interpretation of quantitative data, and successful connections between theoretical models and evidence (Wongvorachan et al., 2024). Moreover, students who have been trained in software environments exhibit greater problem-solving skills because they have to be able to make analytical decisions, consider the accuracy of outputs and modify methods of approach (Hodges et al., 2023). It has also been discovered that communication skills improve, as software tools help students to create tables, charts, and graphical summaries, which make research reporting more transparent (Leeuw & Lovric, 2025). Furthermore, the competencies associated with methodology, e.g. research design and interpretation of data, are more organized and systematic when students are well acquainted with digital tools of analysis. Statistical software can develop statistical and quantitative analysis skills in learners because it gives them a platform to explore data in real-time, model test, and interpret data (Sakaria et al., 2023). The repetitiveness of data processing in software systems contributes to information seeking because students need to consult the sources on a regular basis, discover the variables of interest, and justify their decisions (Wongvorachan et al., 2024). The skills of problem solving are developed with the help of diagnostic reasoning where students compare possible alternative approaches, and optimize analytical results (Rahayu et al., 2024). Moreover, the data display and reporting opportunities of statistical software help to make research findings communicate more successfully and consistently. Equally, a methodological sense of clarity and accuracy is upheld by continued exposure to methodological analytical processes.

H1: The use of statistical software positively influences student research skills

Statistical self-efficacy is the confidence of a student of his or her capability of learning effectively, using and interpreting statistical concepts and procedures. It is anchored in the general process of self-efficacy by Bandura which focuses on the belief in the ability to perform certain activities (Dai et al., 2023). Statistical self-efficacy, in the framework of the development of research skills, affects the way students approach research activities, data, select analysis strategies, and make meaningful conclusions (Heikkilä et al., 2023). Students who had high statistical self-efficacy tend to be more persistent, curious, and oriented to problem solving in their attempts to complete a research task compared to those who have low confidence levels who may be avoidant or simplistic in their approach to analysis of tasks (Anggraeni et al., 2023). Research skills are those set of important skills that are needed when undertaking a systematic investigation and include data analysis, information literacy, critical thinking, presentation of findings and proper selection of research methodologies (Knight, 2025). Thus, internal confidence students have in their skills in doing the statistical tasks is relevant in determining the effectiveness with which they can go about research-oriented learning. It has been empirically confirmed on numerous occasions that students who are more advanced in terms of statistical self-efficacy outperform better in course work related to research and in case of an independent research work (Idek et al., 2025). Findings point to the fact that studying students who develop an idea that they will be able to cope with a statistical analysis tend to be more willing to immerse themselves in data interpretation and the process of making the methodological choice (Limna, 2023). Studies also indicate that academic persistence has a positive relationship with statistical self-efficacy, especially in classes that demand quantitative reasoning (Wongvorachan et al., 2024). Moreover, students who feel rather confident about their level of statistical skills can overcome anxiety regarding numbers, work with software or complicated data structures. There is also an improvement in enhanced communication of research results, where students with higher self-efficacy are more coherent and organized in presenting the results (Clark-Carter, 2024). Once students trust their statistical abilities, they will be more willing to think critically and tenaciously when it comes to analytical tasks, resulting in the better data handling, problem solving and enhanced methodological ability (Hodges et al., 2023). Increased statistical self-efficacy promotes information-seeking and

the use of statistical resources by students and critical evaluation of research evidence, which improves the general research competence (Anggraeni et al., 2023). Also, the ability to read and communicate statistical output is involved in providing easier expression of results, which is one of the major elements of research dissemination.

H2: Statistical self-efficacy positively affects student research skills

Statistical self-efficacy is a significant psychological process, where learning software offers effective opportunities to manipulate, visualizing, and analyze data, how well students use it depends to a decisive degree on their conviction in their capability to accomplish it (Wongvorachan et al., 2024). Those students that work with statistical software often become familiarized with the process of analysis and understanding the results of statistical analysis, and over time, they become more confident in their ability to do quantitative work (Zhang & Han, 2024). Such confidence or statistical self-efficacy helps in motivating learners to be more initiative, persistent and analytical in their research activities (Sakaria et al., 2023). Consequently, the technical exposure is accompanied by the perception of competence in carrying out research that is shaped by the use of statistical software not only in students. The mediating effect of statistical self-efficacy is supported by the empirical studies between the use of software and research skills. Research revealed that the self-efficacy of statistical reasoning among students trained to operate statistical software daily with the support of instructions is enhanced through the use of statistical software (Hodges et al., 2023). Learners who feel successful in passing analytical challenges in software environments tend to have greater self-confidence in their skill in conducting their research independently (Althubaiti & Althubaiti, 2024). On the other hand, unconfident students might not use the software facilities completely when the facilities are available. It has also been proposed that active problem-solving, critical thinking, and methodological decision-making are linked to statistical self-efficacy (Halawa & Harefa, 2024). When the students are exposed to statistical software, they are able to acquire practical experience, which builds their confidence slowly in handling and interpreting data (Rini & Aldila, 2023). This heightened self-efficacy in turn encourages them to use more advanced strategies of analysis, find more sources of information and further diffusion of findings. Consequently, this makes their research more polished and all-inclusive.

H3: Statistical self-efficacy mediates the relationship between the use of statistical software and student research skills

Learning orientation is a motivational and cognitive disposition that reflects a student's intrinsic desire to acquire new knowledge, develop competence, and master challenges through effort and persistence (Obazuaye, 2025). Students with a strong learning orientation tend to value learning as an end in itself rather than as a means to achieve external rewards. In research-based learning contexts, such students are more likely to explore new methods, experiment with data, and engage deeply in analytical tasks (Utomo et al., 2023). When using statistical software, learning-oriented students view the experience as an opportunity to enhance their understanding of statistical concepts and refine their methodological precision (Almutairi, 2025). This orientation not only promotes active engagement but also fosters resilience when encountering technical or analytical difficulties. In contrast, students with low learning orientation may limit their use of software to completing assigned tasks, showing little initiative in exploring additional features or improving their analytical accuracy (Rezende et al., 2023). Empirical research provides strong support for the moderating role of learning orientation in the relationship between software use and research skill development (Zhang & Han, 2024). Studies have shown that students with higher learning orientation exhibit greater persistence and creativity in applying technological tools, leading to deeper conceptual understanding and improved analytical abilities (Pozovna et al., 2023). These students are more likely to adopt reflective and self-directed learning strategies that enable them to identify gaps in their knowledge and seek solutions independently (Kramarov et al., 2023). As a result, they derive greater academic benefits from software-based learning environments compared to students who lack such motivation. The use of statistical software alone provides the means for skill acquisition, but learning orientation determines the depth of engagement and application of those skills (Rini & Aldila, 2023). Therefore, students with a high learning orientation are expected to gain significantly more from statistical software, developing stronger research skills across multiple domains.

H4: Learning orientation moderates the relationship between use of statistical software and student research skills

2.2 Theoretical Framework Supporting the Research

The theoretical background on which the current research model will be based on the Social Cognitive Theory (Bandura, 2001) according to which learning takes place when there is this mutual interaction between the individual factors, behavioural patterns, and the environment. The application of statistical software in this study will be an environmental and teaching aspect that will give learners a chance to engage in the data analysis activities. By continually working with software tools, the students are able to build a statistical self-efficacy which is one of the most important personal cognitive beliefs, and which determines the confident approach towards research tasks that they will be performing. Increased self-efficacy increases persistence, analytical thinking and readiness to solve challenging research problems, which subsequently results in acquisition of student research skills (Zimmerman, 2000). Nonetheless, the degree

to which self-efficacy is converted into skill acquisition is dependent on the learning orientation of a learner which constitutes internal predilections towards enquiring, analysing, thinking in an organized manner, making decisions and reflecting. More oriented learners have higher chances to exercise their statistical confidence in the meaningful way that involves getting involved in methodological reasoning and coming up with well-grounded research products (Elliot & Dweck, 2013). Therefore the model proposes that statistical software application has a direct and indirect positive influence on research skills via statistical self-efficacy, and learning orientation increases the relationship between self-efficacy and research skills. The proposed relationships are depicted in Figure 1, which indicates the mediating role of statistical self-efficacy and moderating effect of learning orientation in the research skill development process.

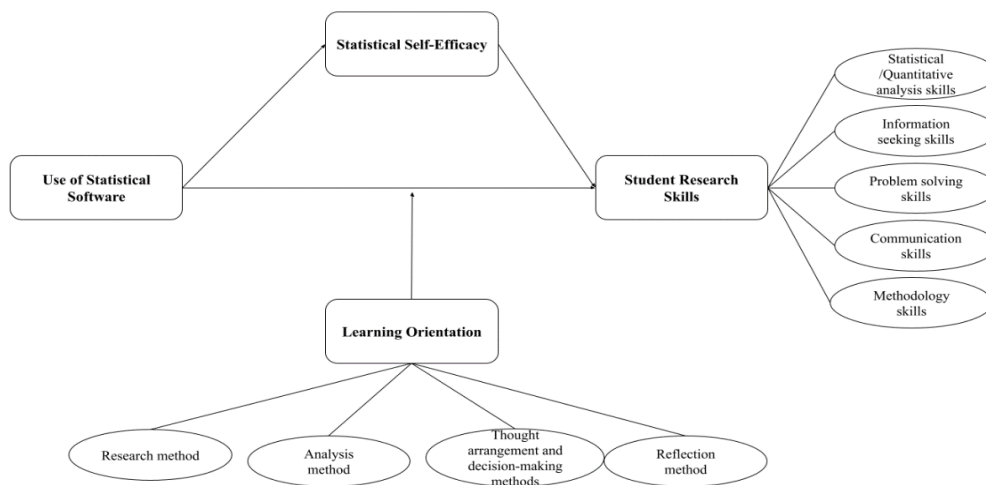


Figure 1: Conceptual Framework

3. Methodology

The current study took a quantitative, cross-sectional research design to investigate the effects of the use of statistical software on the student research skills using the statistical self-efficacy as the mediating variable and learning orientation as a moderating variable. The sample of the study was comprised of 224 undergraduate and postgraduate students who are pursuing either biomathematics and other quantitative courses in different universities which are both public and private. A stratified random sampling method was used to select the participants so that they could be fairly represented in the various institutions, gender, and academic levels. To achieve this, stratification was done according to the type of university (public or private) and the year of study (second, third or fourth) so as to get a variety of student experiences. The selection of participants within each stratum was randomly done to reduce selection bias, as well as enhance the degree of the generalizability of the findings. The inclusion criterion meant that, the students should have completed a minimum of one course in research related or statistics related and have experience in using statistical software such as STATISTICA to complete assignments or projects. This made sure that there was familiarity of the participants with the constructs of study.

The researcher used the four standardized and previously tested tools to assess the key constructs: statistical self-efficacy, learning orientation, student research skills, and statistical software use. Statistical self-efficacy was assessed through a 14-item scale that was created by Finney and Schraw (2003), the scale measured the confidence of students in doing statistical tasks like identifying scales of measurement, interpreting probability values, differentiating between descriptive and inferential statistics, and understanding sampling distributions. The scale used to measure learning orientation was adapted from Woo and Kim (2022), which includes four sub-dimensions (research method 3 items, analysis method 3 items, thought arrangement and decision-making methods 6 items, and reflection method 1 item). The skills of student research were measured in terms of subscales of Meerah et al. (2012), which comprised 10 items that were administered in five dimensions: statistical or quantitative analysis skills (2 items), information seeking skills (2 items), problem-solving skills (2 items), communication skills (2 items), and methodology skills (2 items). Finally, the statistical software measurement was measured on a 2-item scale modified by Brezavšček et al. (2016) that measured the frequency and initiative of students to use software SPSS to analyze data and complete research assignments. Each item was rated on a five point Likert scale of 1 (strongly disagree), 2 (strongly disagree), 3 (strongly disagree), 4 (strongly agree), and 5 (strongly agree) with higher scores representing the degree of confidence, engagement, or proficiency in the related construct.

The data were collected using a structured online questionnaire that was administered over the email networks of universities, student learning management systems, and academic portals to students. Communication took about four

weeks to collect the data. The online platform made possible a massive geographic coverage in various universities and voluntary attendance. The questionnaire contained an introductory part explaining the purpose of the study and the way that it had to be completed. The participants had to affirm that they had successfully taken at least one course related to research in order to play. The survey underwent pilot-testing to make it comprehensible and instrument reliable. After refining, the questionnaire was finalized which was subsequently distributed and generated 250 responses out of which 224 passed screening on completeness and consistency, and hence the questionnaire had a valid response rate of 89.6.

The data obtained were measured with SmartPLS version 4.0, a sophisticated computer-based software of variance-based structural equation modelling (SEM) that is recommended on predictive and exploratory studies. The analysis took place in two major steps which are measurement model assessment and structural model assessment. Evaluation of the measurement model was done initially to establish reliability and validity by assessing the outer loadings, the alpha of Cronbach, composite reliability (CR), and average variance extracted (AVE). Heterotrait-monotrait ratio (HTMT) criterion was the test of discriminant validity that was required to make all constructs empirically different. Subsequently, the structural model was assessed to test the hypothesized relationships based on a bootstrapping method having 5,000 subsamples to identify the levels of significance of path coefficients (β), t-values and p-values. The explanatory power of the model was measured using the values of R-Square (R^2) of the endogenous constructs and Q-square (Q^2 predict) was used to determine the predictive relevance. Root mean square error (RMSE) and mean absolute error (MAE) were obtained and used to determine the overall fit of the model and accurate prediction.

4. Results

Table 1 and Figure 2 show the findings of reliability and validity of all the constructs used in the research. The results show that all variables show a high level of internal consistency and a high level of convergent validity. The variable analysis demonstrates a very good reliability with a Cronbach's alpha of 0.853 and composite reliability (CR) value of 0.911 and its average variance extracted (AVE) of 0.773 demonstrates a convergent validity. On the same note, both communication skills and information seeking skills exhibit high item loadings of above 0.89 and above AVE of above 0.80 indicating that the items measure what they are supposed to measure. The skills of constructs methodology and problem solving skills show also satisfactory internal consistency and all the outer loadings are greater than 0.88, showing the strength of measurement. Despite the fact that reflection method has a low AVE value of 0.594 as opposed to others, it is still within the acceptable range, which proves moderate convergent validity. In addition, research method, statistical analysis, skills, thought arrangement and decision-making methods are both characterized by good reliability and validity with loadings and CR values of over 0.90. The construct statistical self-efficacy and its 14 indicators show good reliability (Cronbach's alpha = 0.956; CR=0.961) and fair AVE (0.64), which proves the consistency of the measure. Finally, two items in the use of statistical software have a very high outer loading (0.903 each) and have a high level of reliability indicators (alpha = 0.774; CR = 0.899; AVE = 0.816), which confirms that the construct was measured accurately.

Table 1 (a): Variables Reliability and Validity

Variables	Items	Outer Loading	Cronbach's Alpha	CR	AVE
Analysis Method	AM1	0.841	0.853	0.911	0.773
	AM2	0.889			
	AM3	0.908			
Communication Skills	CS1	0.907	0.774	0.899	0.816
	CS2	0.900			
Information Seeking Skills	ISS1	0.897	0.760	0.893	0.806
	ISS2	0.899			
Methodology Skills	MS1	0.900	0.753	0.890	0.802
	MS2	0.891			
Problem Solving Skills	PSS1	0.902			
	PSS2	0.889			
Reflection Method	REM1	0.900	0.923	0.936	0.594
Research Method	RM1	0.846	0.791	0.878	0.705
	RM2	0.817			
	RM3	0.856			
Statistical Analysis Skills	SAS1	0.861	0.661	0.855	0.747
	SAS2	0.868			
Statistical Self-Efficacy	SSE1	0.817	0.956	0.961	0.640
	SSE10	0.822			
	SSE11	0.793			
	SSE12	0.746			
	SSE13	0.806			
	SSE14	0.578			

Table 1 (b): Variables Reliability and Validity

Variables	Items	Outer Loading	Cronbach's Alpha	CR	AVE
Thought Arrangement and Decision-Making Methods	SSE2	0.810	0.902	0.924	0.671
	SSE3	0.837			
	SSE4	0.786			
	SSE5	0.879			
	SSE6	0.827			
	SSE7	0.836			
	SSE8	0.816			
	SSE9	0.807			
	TADMM1	0.862			
	TADMM2	0.821			
	TADMM3	0.845			
	TADMM4	0.781			
Use of Statistical Software	TADMM5	0.788	0.774	0.899	0.816
	TADMM6	0.816			
	USS1	0.903			
	USS2	0.903			

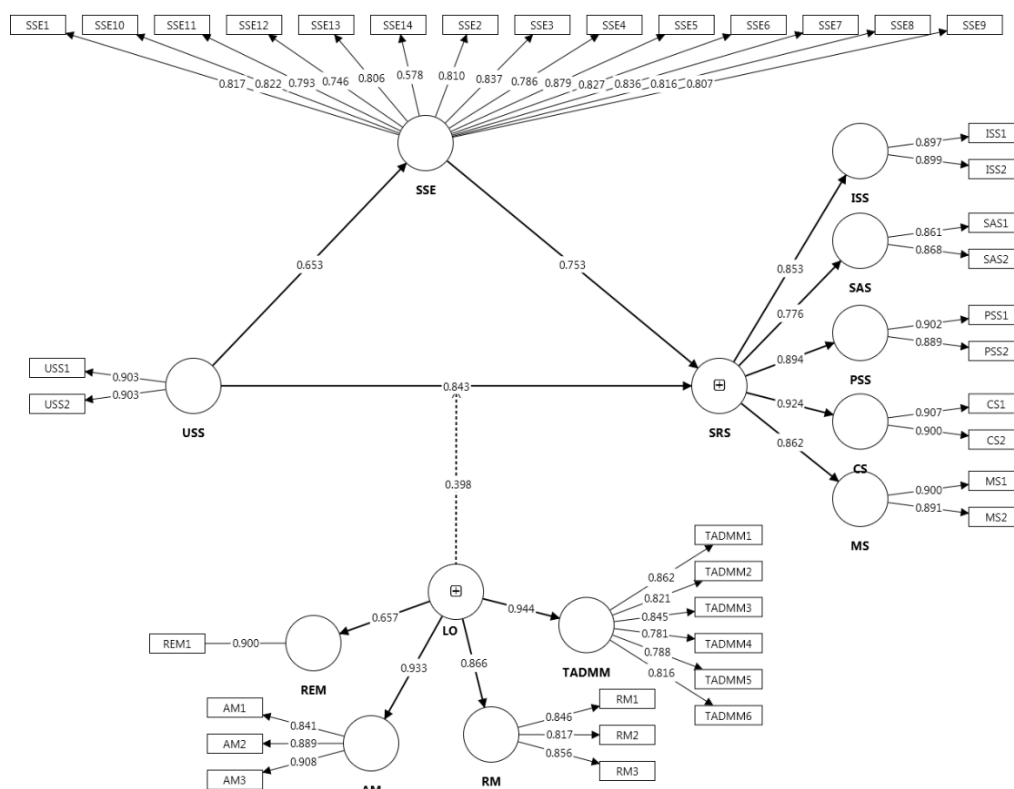
**Figure 2:** Estimated Model

Table 2 presents the study findings on the discriminant validity of all variables in the study assessment based on the heterotrait-monotrait ratio of correlations (HTMT). The values also show that all constructs are independent of each other, with all the HTMT values lower than the conservative of 0.85. The correlation between analysis method verses communication skills (0.684), analysis methodology versus problem solving skills (0.668) indicate moderate correlation indicating that there is a conceptual similarity in these constructs but they are theoretically different. The outcomes also indicate that research method, statistical analysis skills and the information seeking skills have moderate relationship which is natural given that these three dimensions work together in developing skills in research. The statistical self-efficacy correlations with other constructs ($r = 0.511$ to 0.598) imply that although this variable is an interaction with other constructs, it is not a repetition of a dimension. The mediating assumption between the two (0.571) is supported by the statistical software use and statistical self-efficacy relationship that exhibits a significant but independent relationship. On the same note, there are moderate relationships between thought arrangement and decision making methods and other constructs since these two constructs contribute towards cognitive and reflective aspects of learning.

Table 2: Discriminant Validity (HTMT)

	AM	CS	ISS	MS	PSS	REM	RM	SAS	SSE	TADMM	USS
Analysis Method											
Communication Skills	0.684										
Information Seeking Skills	0.643	0.671									
Methodology Skills	0.612	0.637	0.655								
Problem Solving Skills	0.601	0.642	0.671	0.668							
Reflection Method	0.511	0.523	0.53	0.544	0.552						
Research Method	0.574	0.589	0.603	0.621	0.636	0.544					
Statistical Analysis Skills	0.642	0.668	0.651	0.676	0.644	0.617	0.633				
Statistical Self-Efficacy	0.524	0.538	0.556	0.563	0.571	0.511	0.598	0.582			
Thought Arrangement and Decision-Making Methods	0.601	0.619	0.641	0.658	0.672	0.548	0.611	0.639	0.563		
Use of Statistical Software	0.635	0.653	0.669	0.677	0.682	0.559	0.627	0.648	0.571	0.663	

Table 3 presents the values of the R-squared, adjusted R-squared and predictive relevance (Q^2 predict) of the endogenous measures, the general model fit measures such as root mean square error (RMSE) and mean absolute error (MAE). The estimate shows that the R^2 of the predictors of student research skills is 0.848, and the adjusted R^2 is 0.846 which explains that the predictors, use of statistical software, statistical self-efficacy and learning orientation can predict student research skills with an approximate of 85 percent. This is a very high degree of explanatory power and it shows that the model has the ability to capture the key determinants of research competence. The predict Q^2 of 0.853 is not less than zero which means that the model is very predictive and relevant. In the case of statistical self-efficacy, the R^2 and the adjusted R^2 of the model are 0.427 and 0.424 which show that external factors contribute approximately 43 percent of the variance of the variable, i.e., the use of statistical software. Although this value represents a moderate predictive power, it predetermines the fact that the work with analytical tools is significant to influence students in their confidence regarding statistical tasks. The value of RMSE (0.424) and MAE (0.329) of student research skills show that it fits the model well with a minimum predictive error.

Table 3: R-square Statistics Model Goodness of Fit Statistics

Endogenous Constructs	R^2	R^2 Adjusted	Q^2 predict	RMSE	MAE
Student Research Skills	0.848	0.846	0.853	0.424	0.329
Statistical Self-Efficacy	0.427	0.424	0.413	0.775	0.522

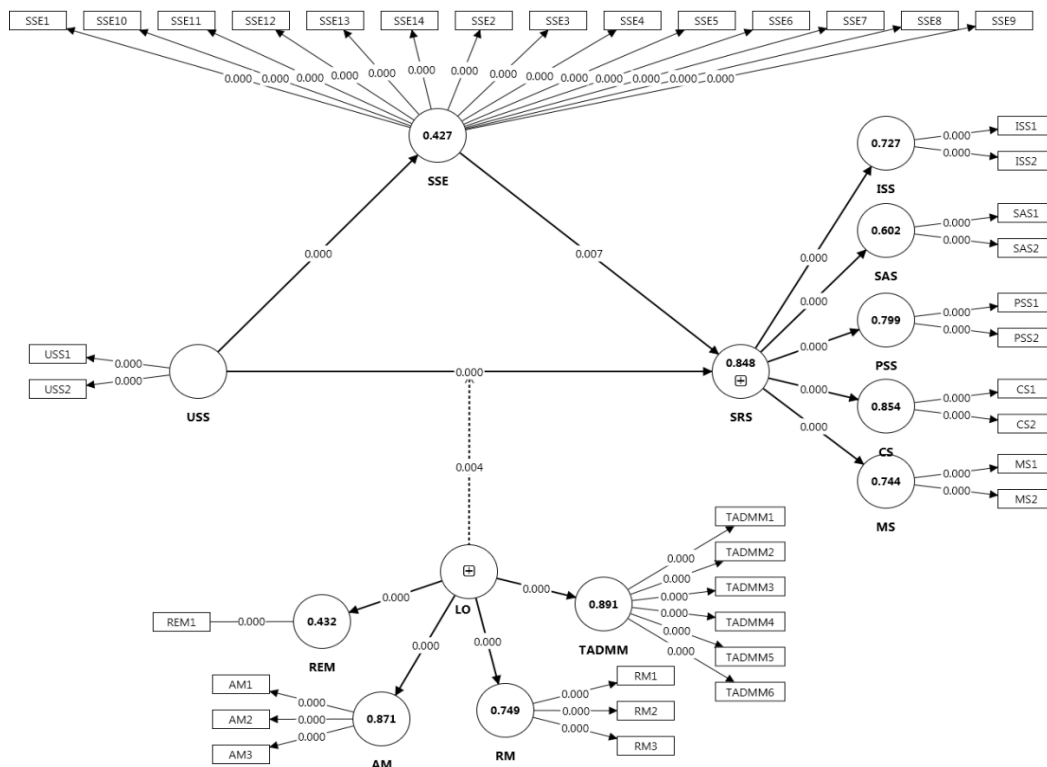
**Figure 3:** Structural Model for Path Analysis

Table 4 and Figure 3 provide the results of the path analysis showing the relationships among the key variables in the structural model. The findings support all four proposed hypotheses, confirming the theoretical assumptions of the study. The first hypothesis, which posited that use of statistical software positively influences student research skills, is strongly supported ($\beta = 0.380$, $t = 8.580$, $p = 0.000$), indicating that software-assisted learning significantly enhances students' analytical, methodological, and problem-solving competencies. The second hypothesis, which proposed that statistical self-efficacy positively affects student research skills, is also supported ($\beta = 0.172$, $t = 2.443$, $p = 0.007$), showing that students' belief in their ability to perform statistical tasks contributes meaningfully to research performance. The third hypothesis confirms that statistical self-efficacy mediates the relationship between use of statistical software and student research skills ($\beta = 0.112$, $t = 2.001$, $p = 0.023$), highlighting that students' confidence acts as an important psychological mechanism through which software use translates into skill development. Finally, the fourth hypothesis is also validated, indicating that learning orientation moderates the relationship between use of statistical software and student research skills ($\beta = 0.011$, $t = 2.041$, $p = 0.004$). This finding suggests that the positive effect of self-efficacy on research skills becomes stronger when students exhibit a high level of learning orientation.

Table 4: Path Analysis

Hypothesis	Statement	β	SE	t-Value	p-Value
H1	The Use of Statistical Software has a Significant Positive Influence on Student Research Skills.	0.380	0.044	8.580	0.000
H2	Statistical Self-Efficacy has a Significant Positive Effect on Student Research Skills.	0.172	0.070	2.443	0.007
H3	Statistical Self-Efficacy Significantly Mediates the Relationship Between the Use of Statistical Software and Student Research Skills.	0.112	0.056	2.001	0.023
H4	Learning Orientation Significantly Moderates the Relationship Between Use of Statistical Software and Student Research Skills, such that the Relationship Is Stronger When Learning Orientation is High.	0.011	0.005	2.041	0.004

5. Discussion

The current research aimed to test the theories of technological, psychological, and motivational influences that occur together to develop the research skills among students pursuing biomathematics classes. With research education increasingly moving towards models that focus on the active learning model to an inquiry-based approach, the requirement of students to have effective analytical, methodological and problem-solving skills has gained more significance. However, these skills are not formed only through the theoretical training; they are developed in the course of the purposeful working with the analytical tools, the belief in personal possibility to complete the complicated tasks, the thoughtful attitude to the life-long learning and reflection. The arrival of statistical software in the academic environment is a significant change in instructions as it provides students with effective tools to deal with actual data and implement the statistical procedures accurately. Meanwhile, internal beliefs and motivations of students determine whether they are able to take advantage of such learning environments or not.

The results associated with the first hypothesis have shown that the application of statistical software produces a significant positive impact on the student research skills, which is consistent with the overall literature which points out the importance of using technological means as a method to learn analytically (Idek et al., 2025). These findings indicate that the student who actively used statistical software exhibited greater skills in a number of areas of research skills such as statistical and quantitative analysis, seeking information, methodological decision-making, problem-solving and results presentation. It means that the software was not only a computation tool but also a cognitive support system which allowed students to engage in work with real data, hypothesizing, processing analytical results, and presenting the findings in a more efficient manner. These findings align with the research conducted in the past, which proves that formal exposure to data analysis software leads to better analytical thinking, conceptual clarity, and trustworthiness in working with empirical data in learners (Wang & Ahmed, 2004). The software feature created both practical and practical learning that enabled the students to transform theoretical statistical information into the practical analytical practice. Also, the visualization tools that included charts and graphs helped the students improve their communication skills as they were able to present complex findings comprehensively and understandably.

The hypothesis that the relationship between statistical self-efficacy and the research skills of students would be positive also proved to be justified, and self-belief and confidence in analytical performance appeared to be the key determinant. The findings suggest that students that possessed greater statistics self-efficacy were more ready to participate in intricate analysis activities, persevere through difficulty and critically evaluate results. This observation is consistent with the concept of Social Cognitive Theory according to which beliefs in abilities can be used by people to play a great role in motivating, working hard, and achieving success in accomplishing a task (Bandura, 2001; Zimmerman,

2000). Students who felt that they were able to comprehend and execute statistical processes were more competent in data analysis as well as in structuring research concepts, assessing evidence, and representing findings. This implies that confidence is a psychological stimulus that fosters more learning and careful usage of research processes. Similar studies in the past show that self-efficacy decreases anxiety, enhances persistence, and enhances academic performance on quantitative courses (Utomo et al., 2023). Besides, the findings suggest that the extent to which students successfully use software tools is largely determined by their self-efficacy beliefs, even in cases where they are provided with such tools. Consequently, to ensure students become strong-research competent, the process of statistical self-efficacy improvement (by guided practice, positive feedback, and team learning) is necessary.

The results involving the third hypothesis established that the relationship between the use of statistical software with the student research skills was established through statistical self-efficacy, which revealed that the effect of the use of the software was not purely technical but also psychological (Halawa & Harefa, 2024). Although statistical software provides the students with the space and resources they need to ensure that they engage in the practice of data analysis, the level of learning and skills acquisition is largely determined by the degree of confidence students gain during their use of the tools. The findings prove that the successful repetitive use of statistical software leads to increased familiarity and comfort in the work with data manipulation, visualization, and interpretation, which, in its turn, improves statistical self-efficacy. This enhanced self-confidence makes students approach research work with a sense of persistence, curiosity and motivation to solve problems that eventually leads to better research skills in areas like methodological reasoning, interpreting data as well as academic communication. These results are consistent with the existing literature that argues that learning environments that are software-supported promote the development of mastery experiences and these experiences are fundamental in developing self-efficacy (Bapanova et al., 2025). In addition, the mediation effect demonstrates that the availability of software does not necessarily result in the better development of research skills; rather, it is the perceived ability of students to utilize the available tools successfully.

The acceptance of the fourth hypothesis that learning orientation moderates the relationship between the use of statistical software and student research skills adds another important dimension to the interpretation of these results by highlighting how individual differences in motivation shape the effectiveness of technology-assisted learning. The findings reveal that students with a strong learning orientation, characterized by an intrinsic desire to acquire knowledge and improve competence, are more likely to derive meaningful benefits from their engagement with statistical software. This aligns with prior research suggesting that learning orientation fosters persistence, curiosity, and self-regulated learning behaviors that amplify the effects of educational technologies on performance (Anggraeni et al., 2023). For such students, the use of statistical software represents not merely a requirement but an opportunity to explore, experiment, and deepen understanding. In contrast, students with lower learning orientation tend to engage with software in a superficial or mechanical manner, thereby limiting the potential for skill enhancement. These results support the notion that motivational dispositions serve as moderators that determine how effectively students transform learning opportunities into actual skill acquisition (Zhang & Han, 2024). Learning-oriented students are more resilient in addressing analytical challenges, more reflective in evaluating outcomes, and more adaptive in integrating feedback all of which contribute to stronger research skills. This moderating effect highlights that even when technological and instructional resources are uniformly provided, the degree of skill development varies based on students' motivational profiles.

The collective affirmation of all four hypotheses shows that learning in terms of developing research skills is a multidimensional phenomenon that is influenced by technological support, self-confidence, and learning attitude. Direct improvement in research skills is in part aided by the use of statistical software but also improves statistical self-efficacy, which also leads to the improvement of skills. Also, the observation that learning orientation moderates the relationship between use of statistical software and research skills underscores the fact that confidence should be complemented by reflective and strategic learning behaviors among students to be able to turn capability into performance.

6. Implications

The results of the study have important theoretical implications in the process of understanding the interaction of technological, psychological and motivational variables to affect the development of research skills in students. The research has a theoretical foundation based on the social cognitive theory, but it goes a step further to prove how interactions of environmental factors like the utilization of statistical software with the internal cognitive variables, that is, the statistical self-efficacy, facilitates student-research performance. The fact that all hypotheses are accepted is a scientifically proved idea that learning is a two-way process that consists of behavior, cognition and environment interaction. In addition, it broadens the theoretical framework in the study by introducing the concept of learning orientation as a moderating construct, incorporating motivational and reflective aspects of student learning as a conceptual gap within the current literature, which tends to view self-efficacy as an independent factor. This integration aids a multi dimensional perception of the skill development where confidence of the ability should be congruent with a growth oriented learning

mentality to deliver efficient results. In theory, the study highlights the fact that technology and learning outcomes cannot be solely related to each other; however, their connection is mediated by the cognitive beliefs and moderated by the individual learning orientations. The tested framework therefore offers a novel conceptual framework to future researchers aiming at examining technology-enhanced learning among scientific and applied field of study, with the significance of the self-efficacy and motivation as instrumental bridges between the digital learning environments and practical research abilities.

The practical significance of the study is very pertinent to instructors and curriculum developers and policy analysts in higher education who seek to enhance research training and analytical literacy of the students in biomathematics and other STEM-related courses. The findings indicate that when statistical software like STATISTICA are incorporated in the construction of the course, critical thinking, problem solving, and methodological knowledge of the students is greatly improved. Therefore, teachers are advised to offer systematic and practical training in software based data analysis to make sure that students are in a position to put the statistical methods into practice in the research situations. Moreover, the fact that statistical self-efficacy plays an important role means that not only analytical procedures are to be taught but the students are also to be provided with the confidence with the help of guided practice, feedback, and scaffold learning activities. Self-efficacy could also be enhanced through mentorship programs and collective learning experience, where peer support and common problem-solving opportunities are provided. Moderating role of learning orientation indicates the significance of encouraging reflective and inquiry classrooms where curiosity, critical thinking and independent exploration are stimulated. The institutions can also think of incorporating reflective learning units and decision making activities into research classes in order to instill a positive learning attitude. On the whole, the results can offer practical solutions to improve research education: practice with technology as a practical application, development of self-belief as a psychological motivator, and development of learning orientation as a motivational base to develop all-rounder research competent graduates.

7. Limitations and future research Directions

Even though the current study makes great contributions on the effects of using the statistical software, statistical self-efficacy, and learning orientation on the acquisition of research skills by biomathematics students, one must note some limitations that would put the results into perspective. To begin with, the research has used a cross-sectional research design that prevents the researcher to draw conclusions about the causality between the variables. Though, considerable relationships have been found, longitudinal or experimental research might be more helpful in reflecting the developmental character of self-efficacy and acquisition of research skills with time. Second, the research sample was limited to biomathematics students, which, even though it is the right choice in the context of the study, limits the application of findings to other fields like engineering, computer science, or social sciences in which the nature of research skills and statistical training can vary. The model needs to be replicated in other fields in the future to determine its generalizability. Third, the research was based on the self-reported data, which can introduce the social desirability and subjectivity; subsequent research can use the performance-based tests or teacher rating to give more objective evidence of the research skill improvement. Also, the research targeted a particular software, namely, STATISTICA, although other mathematical analysis tools like SPSS, R, and Python might vary in their usability and learning outcomes. Research comparing different statistical platforms in terms of their effect on learning effectiveness and research performance could be conducted. Further, although the study reviewed the learning orientation as a moderate variable, additional research in this field might explore other psychological variables like academic motivation, cognitive flexibility, or digital literacy to create a more holistic view of the research skill formation. It is possible that cultural and institutional variables are moderating the relationships as well; hence cross-cultural research may demonstrate how educational background and access to resources makes the difference between the effectiveness of software-based learning. Lastly, in future studies or research, qualitative approach like interviews or focus group would be used to understand more about the lived experiences of students, their perception and difficulty in the acquisition of research competencies using statistics tools.

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