

Leveraging Authentic Learning and Open Data to Foster Epistemic Curiosity and Statistical Reasoning in Biostatistics Education

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ABSTRACT

Purpose: The purpose of this study is to examine the relationships among authentic learning and real-world application, learning self-efficacy, epistemic curiosity, intrinsic learning goal orientation, and student statistical reasoning in biostatistics education. The study specifically explores how authentic learning and learning self-efficacy contribute to the development of epistemic curiosity, how intrinsic learning goal orientation shapes these relationships, and how epistemic curiosity explains the link between instructional and motivational factors and student statistical reasoning. The use of open datasets is emphasized as a contextual foundation for promoting research literacy. **Method:** A quantitative, cross-sectional research design was employed. Data were collected from biostatistics students using established and validated measurement scales adapted from prior studies. Partial Least Squares Structural Equation Modeling (PLS-SEM) was used to test the proposed research model, including direct relationships, moderating effects, and mediation pathways among the study variables. **Findings:** The results indicate that authentic learning and real-world application, as well as learning self-efficacy, positively influence epistemic curiosity. Intrinsic learning goal orientation strengthens the relationships between both authentic learning and epistemic curiosity and between learning self-efficacy and epistemic curiosity. Furthermore, epistemic curiosity mediates the effects of authentic learning and learning self-efficacy on student statistical reasoning, highlighting its central role in translating instructional design and motivational beliefs into higher-order reasoning outcomes. **Originality/Implications:** This study presents an integrated motivational instructional framework for biostatistics education, demonstrating how epistemic curiosity connects authentic learning and self-efficacy to statistical reasoning. The findings offer practical guidance for designing learner-centered, data-driven biostatistics curricula that leverage open datasets to enhance research literacy.

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1. Introduction

The increasing centrality of data-driven decision making in health sciences, life sciences, and public policy has positioned biostatistics education as a foundational component of higher education curricula (Ittenbach, 2023; Slade et al., 2023). Modern statistical and quantitative education studies report a significant reduction in the focus on specific procedural competency in favor of more general outcomes including research literacy, critical interpretation, and meaningful application of empirical evidence (Naveed et al., 2024; Tanus et al., 2025). This shift has created a long-standing academic controversy over the role of instructional design and learner motivation in contributing to higher-order learning outcomes, specifically student statistical reasoning, and not in the acquisition of a specific skill partway in isolation (Bromage et al., 2022; Frisby, 2025).

Another avenue of study focuses on authentic learning and real-world application as a reaction to historical issues regarding the issues of superficial learning and never-ending misperceptions that conventional statistics teaching encourages (Batdi, 2023; D'Arrigo et al., 2024). Empirical research always suggests that programs based on real-world datasets, project work, and applied research challenges can increase conceptual knowledge, transfer, and interpretation (Akgün et al., 2022; Diaz Eaton et al., 2025; Dickson et al., 2025). The increasing access to open datasets provided by the agencies of public health, epidemiological studies, and biological repositories has also increased the potential of real-world

learning, where students can face authentic uncertainty, variability and contextual constraints of biostatistical practice (Bové et al., 2023; Nachtigall & Firstein, 2024). Nevertheless, the previous studies warn that even genuine learning conditions can overwhelm a learner in case of the lack of motivational and regulatory support, which results in disengagement or ineffective learning strategies (Follmer, 2023; Shin, 2024). Such results indicate that authentic learning ought to be studied in conjunction with motivational constructs and not as a separate instructional situation.

Some of these motivational constructs are learning self-efficacy which has been studied extensively in the quantitative and medical education setting (Nachtigall & Firstein, 2024). Basing the research on the Social Cognitive Theory, it is continuously shown that students with a higher level of learning self-efficacy become more persistent, more strategic, and more confident in solving complex statistical problems (Gobinath et al., 2024; Kang et al., 2019). Research findings also show that self-efficacy is related to better conceptual learning and academic self-control in courses about statistics (Follmer, 2023; Naveed et al., 2024). However, the empirical data is still inconsistent with the ways learning self-efficacy is converted to more advanced thinking results. Some researchers find direct impacts on achievement, whereas other researchers indicate the indirect effects of it through motivational and cognitive mechanisms, including curiosity, engagement, and self-regulated learning (Batdi, 2023; Shin, 2024). Such contradictions indicate the necessity of integrative frameworks that explain the relationship between learning self-efficacy and the instructional design under real learning conditions.

This has seen the emergence of epistemic curiosity as an especially prospective but least explored construct. Epistemic curiosity is previously associated with seeking deeper information, generating explanations, and integrating knowledge, which are features of the statistical reasoning and research literacy (Binu et al., 2020; Wright et al., 2025). Research in the field of e-learning and quantitative situations also demonstrates that epistemic curiosity facilitates self-regulated learning and enduring engagement, especially in the situations when the learners are faced with uncertainty or lack of knowledge (Akgün et al., 2022; Shin, 2024). Although this aspect is theoretically relevant, little empirical research has been conducted on the role of epistemic curiosity in education in statistics and biostatistics. The current literature tends to understand curiosity as a relatively stable characteristic, instead of a situational motivational condition that is created by an instructional design and cognitions of a learner (Dwivedi, 2022; Naveed et al., 2024). Consequently, there is continuing discussion over whether epistemic curiosity is an antecedent or a mediator or a consequence of effective data-intensive learning experience.

Similar debates have also been raised regarding intrinsic learning goal orientation that has been associated with deep learning strategies, conceptual understanding and long-term engagement in educational conditions (Akgün et al., 2022). Studies that are based on the Self-Determination Theory have indicated that students who have a high intrinsic learning goal orientation tend to focus more on mastery, exploration, and understanding, especially in inquiry-based and problem-based teaching and learning environments (Benbassat, 2024; Wahyuni et al., 2025). Nevertheless, there are still partial empirical results on its role. Intrinsic learning goal orientation is a predicted factor of achievement in some studies, and a conditional factor in influencing how learners react to design and motivational requirements in instructions (Sabbag et al., 2025; Yañez et al., 2023). This inability to reach a unanimous agreement highlights the importance of investigating intrinsic learning goal orientation as a situational determinant in the framework of holistic explanatory models.

The student statistical reasoning at the outcome level is becoming an essential outcome indicator of significant learning in statistics education. The previous studies focus on the fact that statistical reasoning is not limited to the technical computation but also encompasses the interpretation, assessment of evidence, and prevention of misconceptions (Batdi, 2023; Dehyouri et al., 2011). Despite the fact that authentic learning, learning self-efficacy, epistemic curiosity, and intrinsic learning goal orientation have all been linked to a better reasoning, most empirical studies examine these variables separately or in simple linear relationships (Gómez-Blancarte et al., 2025; Peters et al., 2022). Therefore, no integrative models are found in the literature that can be used to describe the dynamic interaction process between instructional design, motivational beliefs, and cognitive outcomes.

A number of gaps are as such unresolved. Limited number of studies have investigated the joint effect of the authentic learning and real-world application and learning self-efficacy on epistemic curiosity under one analytical model (Al Labadi & Ly, 2025). In addition, epistemic curiosity in the mediating position between instructional experiences and student statistical reasoning is a topic of limited empirical studies in biostatistics education (Dwivedi, 2022; Naveed et al., 2024). Other possible moderating variables that have been overlooked are the intrinsic learning goal orientation which should have strong theoretical grounds (Yañez et al., 2023). Sealing these gaps is needed to further the theory and guide the creation of effective, data-rich teaching of biostatistics.

2. Literature Review

The application of publicly available datasets in teaching biostatistics has become a viable strategy to facilitate research literacy and enhance the process of engagement with the actual scientific inquiry in students (Stoudt et al., 2022). As is noted in the existing literature, exposure to real health and life science data allows students to gain a better conceptualized

approach to statistical concepts by challenging their complexity, uncertainty, and contextual nature of empirical research (Dickson et al., 2025). In contrast to simulated or textbook-based data sets, open data sets compel learners to deal with problems of missing data, measurement bias, data cleaning, and ethical use of information, all needed elements of good research practice (Ignjatović & Stevanović, 2023). Scholars believe that this practical encounter helps students to develop research questions, choose relevant analytical methods and interpret statistical results in a biologically and clinically significant manner (Bové et al., 2023). Moreover, open data interaction also adheres to the principles of open science and promotes transparency, reproducibility, and criticism of sources of data (Slade et al., 2023). Through the use of open datasets in teaching biostatistics, previous research indicates that students do more than learn technical analytical skills when taught biostatistics, but also learn more about research literacy, such as critical thinking, methodological rigor, and the ability to think intelligently about scientific evidence (Naveed et al., 2024).

3. Hypotheses

Empirical studies have always proven that real life application and authentic learning environment is important in arousing epistemic curiosity of students (Nachtigall & Firstein, 2024). Research in post-secondary education and in STEM settings demonstrates that learners are more influenced by real life challenges, real world data, and applied activities, which then result in an increase in cognitive processing and further more inquiry-focused learning processes (Wahyuni et al., 2025). Epistemic curiosity has been associated with authentic learning, amplified questioning, investigations, and the urge to resolve knowledge gaps, which are fundamental aspects of epistemic curiosity (Diaz Eaton et al., 2025). Statistical, science-education, and problem-based learning studies indicate that exposure of students to real-world data situations that are intricate and problem-based influence them to ponder assumptions and find explanatory insight instead of answers that are superficial (Gobinath et al., 2024). Furthermore, empirical data indicate that perceived task value and relevance are also boosted by the use of authenticity and subsequently lead to the desire to seek additional information and clarification by the learner (Benbassat, 2024). All these findings indicate that real-life learning situations are potent antecedents of epistemic curiosity because they match learning tasks with the real-life significance.

Based on empirical results, authentic learning and real world practicing can be hypothetically theorized as pivotal factors of epistemic curiosity in that they place the students as active knowledge makers instead of mere receivers (Peters et al., 2022). Students will be more apt to experience cognitive disequilibrium in situations where they face real-world problems that do not have predetermined solutions, which is what causes curiosity-related information seeking (Dwivedi, 2022). Real-life situations introduce learners to uncertainty, ambiguity and imperfect data as well which provoke their curiosity because of their awareness of knowledge gaps (LeBlanc et al., 2022). In contrast to decontextualized activities, practical scenarios demand interpretation, justification, and reasoning, and these processes invariably arouse epistemic curiosity (Bromage et al., 2022). What is more, the empirical research indicates that authenticity makes the learners feel more relevant and possessive, making them more willing to delve into the underlying mechanisms and cause-and-effect explanations (George & Leon, 2023). Consequently, it should be assumed that an authentic learning and real-life application have a considerable positive impact on epistemic curiosity as they establish inquiry, exploration, and continued intellectual involvement.

H1. Authentic learning & real-world application significantly influence the epistemic curiosity.

The earlier studies have defined learning self-efficacy as a major motivational factor that can affect the cognitive engagement and exploration behavior among students (Frisby, 2025). Empirical research in educational psychology as well as in learning sciences demonstrates that high self-efficacy students have greater confidence in their capability to learn complex content and persist with demanding tasks and control their learning processes (Taylor et al., 2023). Such trust has been identified to have a positive correlation with the curiosity-related behaviors like questioning, exploration, and seeking more information (D'Arrigo et al., 2024). Self-efficacy in teaching quantitative and statistics has been found to decrease anxiety and enhance desire to work with unfamiliar or challenging problems, thus supporting more enquiry (Stoudt et al., 2022). In addition, empirical results indicate that learners who have high levels of self-efficacy tend to perceive challenges as learning opportunities, as opposed to threats, which is also strongly related to epistemic curiosity (Ignjatović & Stevanović, 2023).

Based on such findings, learning self-efficacy can be placed as a direct antecedent of epistemic curiosity since it influences the perception of learners with regard to the level of competence and control in learning scenarios (Slade et al., 2023). The students who engage in thinking that they are capable of effective interaction with academic activities are more likely to face uncertainty and seek knowledge gaps, which are essentials of epistemic curiosity (Akgün et al., 2022). High self-efficacy helps to decrease the fear of failure and cognitive avoidance that helps the learners to approach the complex problems with interest instead of fear (Shin, 2024). The empirical study also indicates that self-efficacy also increases intrinsic motivation and persistence, which also scenario aids continued curiosity-driven inquiry (Boke et al., 2025). Self-

efficacy is useful in learning settings where students are required to analyze data and reason statistically, where students can trial and error, skeptical of the outcome, and seek more profound explanations (You et al., 2025). Therefore, based on empirical findings learners are therefore theorized to be in a position to positively and significantly exert influence on epistemic curiosity on learning self-efficacy.

H2. Learning self-efficacy significantly influence the epistemic curiosity.

Empirical research on goal orientation demonstrates that intrinsic learning goal orientation enhances the ability of students to be engaged in meaningful and challenging learning activities (Wright et al., 2025). Studies indicate that high intrinsic motivation among learners is driven by their knowledge, mastery and intellectual development instead of extrinsic achievements. Such students show increased levels of curiosity, persistence and cognitive flexibility in a real-world and authentic learning context (Batdi, 2023). The existing research indicates that intrinsic goal orientation enhances the influence of instructional strategies with relevance, complexity, and autonomy focus (Al Labadi & Ly, 2025). Research on problem-based learning and inquiry-based learning situations has indicated that authenticity is especially successful at arousing interest in learners who attach importance to learning as an end in itself (Yañez et al., 2023).

According to the empirical evidence, intrinsic learning goal orientation is supposed to play the role of a moderator, which exerts a positive effect on the influence of authentic learning on epistemic curiosity (Gómez-Blancarte et al., 2025). It helps learners have personal objectives because they will have a reason to view practical issues as a way of exploration and not as a scholarship (Beebe et al., 2024). This orientation increases sensitivity to authenticity cues including relevance and complexity increasing responses of curiosity. On the other hand, less strong-minded students can play with real tasks in an instrument-only way, which restricts the curiosity activation process (Sabbag et al., 2025). Empirical evidence confirms the opinion that the intrinsic goal orientation reinforces the motivational pathways where authentic learning contributes to the inquiry behaviors (Ittenbach, 2023). Thus, the hypothesis is that intrinsic learning goal orientation plays an important mediating role in the relationship between authentic learning and epistemic curiosity whereby closer the relationship between authentic learning and epistemic curiosity, the more positive is the relationship is between the intrinsic learning goals and authentic learning.

H3. Intrinsic learning goal orientation significantly moderates the relationship of authentic learning & real-world application and the epistemic curiosity.

Past studies conjecture that the connection between self-efficacy and curiosity is not consistent among learners and can be affected by inner motivational orientations (Tanus et al., 2025). Empirical evidence suggests that learners who have an intrinsic learning objective tend to convert confidence more to exploratory behavior (Follmer, 2023). Where a self-efficacy gives the belief in the capability, it is the intrinsic goal orientation which decides whether the capability is applied in mastery and inquiry (Dickson et al., 2025). The studies on motivation and self-regulated learning have revealed that the high students are more curious, engaged and persistent in complex learning tasks because they are high in self-efficacy and intrinsic goals (Bové et al., 2023).

Based on this evidence, intrinsic learning goal orientation is supposed to enhance the impact of learning self-efficacy on epistemic curiosity (Naveed et al., 2024). High self-efficacy is not enough to result into performance-based or efficiency-based behavior without the presence of intrinsic goals that underline the importance of understanding (Shin, 2024). In case learners are intrinsically oriented, their confidence is more apt to be directed into inquisitive discovery and questioning. The interplay between competence beliefs and goal orientations has been supported by empirical studies to predict the results of deep learning (Diaz Eaton et al., 2025). Therefore, intrinsic learning goal orientation enhances motivational system where self-efficacy promotes curiosity of epistemology (Wright et al., 2025). To this end, this study estimates that the hypothesis about the existence of an intrinsic learning goal orientation moderates the connection between learning self-efficacy and epistemic curiosity.

H4. Intrinsic learning goal orientation significantly moderates the relationship of learning self-efficacy and the epistemic curiosity.

Empirical data has indicated that the way of authentic learning serves to enhance better statistical reasoning although, in this case, it is demonstrated that the analytical process requires the active participation of learners in inquiry and exploration (Peters et al., 2022). Research on the teaching of statistics and data science shows that practical problems lead to better conceptual knowledge, understanding of interpretation and critical thinking (Yañez et al., 2023). Nevertheless, the literature also indicates that these effects can be caused by motivational and cognitive mechanisms, but not by direct instructional exposure (Bromage et al., 2022). The epistemic curiosity has been proposed as a major tool that can connect learning settings with high-levels of reasoning because inquisitive learners tend to challenge assumptions, seek other possible explanations, and combine evidence (Sabbag et al., 2025).

According to the current results, it is possible to conceptualize epistemic curiosity as a mediating process that helps to describe how authentic learning can be converted to a better statistical reasoning. Real world tasks are known to provoke curiosity since they pose ill-structured problems and meaningful data, thus, stimulates deeper processing of information and reflective thinking (Follmer, 2023). Interested learners will tend to reason and think iteratively, critically assess evidence,

and make interpretations more refined, which are key elements of statistical reasoning (Ignjatović & Stevanović, 2023). Empirical studies prove the potential of curiosity as an intermediary between the learning setting and cognitive behavior (Akgün et al., 2022). Thus, the hypothesis is that epistemic curiosity plays a major role in mediating the relationship between authentic learning and student statistical reasoning.

H5. Epistemic curiosity significantly mediates the relationship of authentic learning & real-world application and the student statistical reasoning.

The previous research suggests that the self-efficacy learning process has a positive relationship with the statistical reasoning skills of students such as interpretation, problem-solving, and analytical confidence (Wahyuni et al., 2025). Nevertheless, empirical studies indicate that self-efficacy is not a complete explanation of the increases of reasoning results (Benbassat, 2024). The interest based learning has been proved to be very important in converting confidence to meaningful cognitive action among learners (You et al., 2025). Quantitative learning Research studies have shown that students with high self-efficacy effectively seek explanations and delve into data patterns thus becoming better at reasoning (Al Labadi & Ly, 2025).

Basing on this evidence, epistemic curiosity is hypothesized as a mediating variable that can be used to explain the role of learning about self-efficacy in resulting in improved statistical reasoning (LeBlanc et al., 2022). Self-efficacy gives the feeling of confidence to do complex statistical work, and epistemic curiosity makes learners dig deeper, challenge findings and pursue conceptual clarity (Beebe et al., 2024). Curious students tend to have more elaborative processing and reflective assessment, which is needed to gain effective statistical reasoning. The empirical evidence confirms the idea that curiousness is a factor that converts motivational beliefs to cognitive results (Frisby, 2025). The hypothesis is therefore that epistemic curiosity plays a significant role in mediating the relationship that exists between learning self-efficacy and student statistical reasoning.

H6. Epistemic curiosity significantly mediates the relationship of learning self-efficacy and the student statistical reasoning.

3.1 Hypothetical Basis of the Research Model

The hypothesized research model is theoretically based on the Social Cognitive Theory, Self-Determination Theory, and Epistemic Curiosity Theory. The Social Cognitive Theory describes the influence of self-efficacy learning on student motivation, involvement and perseverance in difficult learning activities (Tanus et al., 2025). The Self-Determination Theory brings out the importance of intrinsic learning goal orientation in the development of autonomous motivation and profound involvement, especially in genuine learning experiences (Stoudt et al., 2022). The Epistemic Curiosity Theory is a cognitive-motivational theory of inquiry and exploration, which suggests that when faced with uncertainty and knowledge gaps, their exposure leads to inquiry and exploration (Bové et al., 2023). The joints of these theories illustrate the role of authentic learning and self-efficacy in determining the effects of epistemic curiosity, the presence of intrinsic goal orientation enhances the effects of these two variables, and the role of curiosity as a core process toward the development of better statistical reasoning. This combined theoretical construct facilitates the suggested moderated mediation model and provides a consistent explanation of the motivation and cognitive mechanisms of research literacy development (Figure 1).

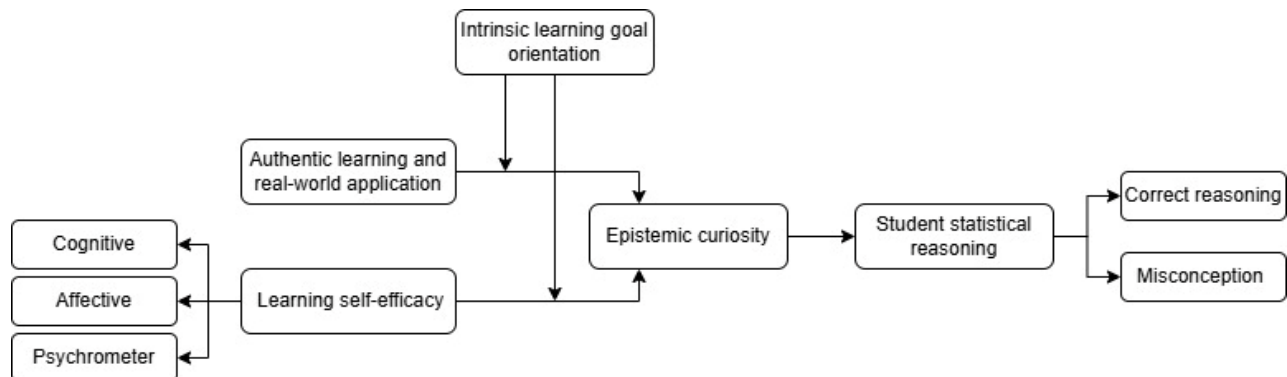


Figure 1: Conceptual Framework

4. Methodology

4.1 Research Design

The research design used in the study was a quantitative and cross-sectional research design to investigate the links

between authentic learning and real-life practice, learning self-efficacy, intrinsic learning goal orientation, epistemic curiosity, and student statistical reasoning in the framework of biostatistics education. The approach followed was theory-based where hypotheses were formulated on the basis of existing motivational and learning theories and empirically validated through structural equation modeling. The cross-sectional design was deemed suitable to reflect the perceptions of students, their beliefs in motivation and the learning outcomes of the students at a given time enabling the researcher to test both the direct and indirect correspondence of the study variables.

4.2 Participants and Sample

The research was carried out on the undergraduate and graduate students taking courses in biostatistics. The number of students who were involved in the study was 277, and this formed the final sample on which data analyses were made. The sample size was bigger than the required minimum standards used in Partial Least Squares Structural Equation Modeling (PLS-SEM), and thus there was sufficient statistical power to estimate complex models that require modification and mediation effects. The respondents were of varying academic levels in the life and health sciences, which also gave a realistic portrait of learners normally involved in biostatistics training. The study population of biostatistics students was suitable because the researchers were interested in statistics reasoning and research literacy.

4.3 Measures and Instrumentation

The measurement scales, which were applied in this study, were all borrowed and validated scales reported in previous empirical studies. The content validity and reliability of the measurement model were improved by the utilization of already tested scales. A multi-item scale indicating the interaction of students with applied task and real data situations was used in the measurement of authentic learning and real-world application. The self-efficacy construct was operationalized as a multidimensional construct, which included affective, cognitive, and psychomotor scores, indicating the confidence of the students to cope with statistical learning tasks. Intrinsic learning goal orientation was determined by items that examined mastery-oriented learning goals and intrinsic motivation to understand. Epistemic curiosity was measured using items that reflected the students wish to learn something, seek the unknown, and seek answers. Indicators included in measuring the student statistical reasoning were those that reflected correct reasoning and misconceptions. Table 1 provides detailed data on sources of scale, description of items and properties of measurement.

Table 1: Questionnaire Development

Construct	Items	Source
Authentic Learning and Real-World Application	05	(Indriati et al., 2024)
Learning Self-Efficacy	15	(Kang et al., 2019)
Epistemic Curiosity	10	(Binu et al., 2020)
Student Statistical Reasoning	15	(Dehyouri et al., 2011)
Intrinsic Learning Goal Orientation	03	(Xie, 2011)

4.4 Data Collection Procedure

The structured questionnaire was used in data collection where data were gathered among the biostatistics students within the school term. The questions in the questionnaire captured the key constructs of the study as well as the demographic data. The participants were asked to provide their response in the form of a Likert type scale which is widely used in educational and psychological studies to measure perceptions and attitudes. The data were filtered in advance to detect the absence of values, outliers, and contradictions. Only full and valid responses were retained and a final dataset of 277 observations obtained. The data were coded and then ready to be analyzed statistically.

4.5 Data Analysis Technique

The data analysis was conducted with the help of the Partial Least Squares Structural Equation Modeling (PLS-SEM), and it was conducted in two steps according to which the measurement model and the structural model were evaluated. The reason why PLS-SEM was chosen is that it is applicable in the case of complex models that have many constructs, moderation, and mediation effects and that it can be used with moderately large sample sizes. Measurement model was tested by indicating the evaluation of reliability of indicators, internal consistency reliability, convergent and discriminant validity. The structural model analysis was done based on path coefficients, effect sizes (f^2), coefficient of determination (R^2), predictive relevance and hypothesis testing. To determine the statistical significance of the hypothesized relationships, bootstrapping procedures using a high resamples were used. This type of analysis allowed a thorough study of the research model suggested and it was possible to have empowered empirical evidence on the research hypotheses.

5. Results

The findings of the evaluation of the measurement model are in the form of a table as the table 2 where reliabilities of the indicators of all latent constructs involved in the study were assessed together with Internal consistency reliability and convergent validity. The first indicator that was tested in terms of reliability was in the case of outer loading; the majority of the items showed good loadings of more than the recommended level of 0.60, meaning that the indicators sufficiently reflect the constructs that they represent. The construct of authentic learning and real-world application had item loading scores of between 0.634 and 0.783 indicating indicator's reliability that is satisfactory. Equally, epistemic curiosity had acceptable loadings of between 0.583 and 0.770 as far as exploratory and social science research is concerned. The loading of intrinsic learning goal orientation showed the highest loadings and one of the indicators had the highest loading of 0.978 meaning very strong relationship with the latent construct.

Table 2: Variables Reliability and Validity

Variable	Indicator	Original Sample	Cronbach's Alpha	Composite Reliability	AVE
Authentic Learning and Real-World Application	ALRW1	0.634	0.773	0.847	0.526
	ALRW2	0.722			
	ALRW3	0.783			
	ALRW4	0.783			
	ALRW5	0.695			
Epistemic Curiosity	EC10	0.583	0.871	0.899	0.528
	EC3	0.770			
	EC4	0.749			
	EC5	0.764			
	EC6	0.751			
	EC7	0.715			
	EC8	0.750			
	EC9	0.715			
	EC9	0.715			
Intrinsic Learning Goal Orientation	ILGO1	0.765	0.762	0.869	0.771
	ILGO2	0.978			
Learning Self-Efficacy			0.904	0.918	0.546
Affection	LSEA1	0.742	0.762	0.849	0.584
	LSEA2	0.778			
	LSEA3	0.748			
Cognitive	LSEA4	0.786	0.877	0.907	0.619
	LSEC1	0.788			
	LSEC2	0.801			
	LSEC3	0.780			
	LSEC4	0.835			
	LSEC5	0.771			
	LSEC6	0.744			
Psychomotor	LSEP1	0.671	0.776	0.857	0.602
	LSEP2	0.819			
	LSEP3	0.801			
	LSEP4	0.803			
Student Statistical Reasoning			0.826	0.822	0.586
Correct Reasoning	SSRC1	0.638	0.868	0.897	0.522
	SSRC2	0.781			
	SSRC3	0.771			
	SSRC4	0.722			
	SSRC5	0.727			
	SSRC6	0.728			
	SSRC7	0.645			
	SSRC8	0.755			
Misconception	SSRM1	0.680	0.887	0.910	0.594
	SSRM2	0.783			
	SSRM3	0.727			
	SSRM4	0.704			
	SSRM5	0.793			
	SSRM6	0.842			
	SSRM7	0.848			

Cronbach alpha and composite reliability (CR) were used in determining internal consistency reliability. All constructs were greater than the suggested minimum levels of 0.70 of both measures, which validated high-quality reliability. There was a high level of internal consistency between constructs as the values of Cronbach alpha ranged between 0.762 to 0.918 whilst the values of composite reliability ranged between 0.847 and 0.910. The average variance extracted (AVE) was used to assess convergent validity, and all constructs have the minimum criterion of 0.50. The values of AVE ranged between 0.526 and 0.771, which shows that every construct contributes to over half of its indicators. In general, Table 2 of the results proves that the measurement model has reasonable reliability and convergent validity and serves as a good background to the further analysis of the structural model (Figure 2).

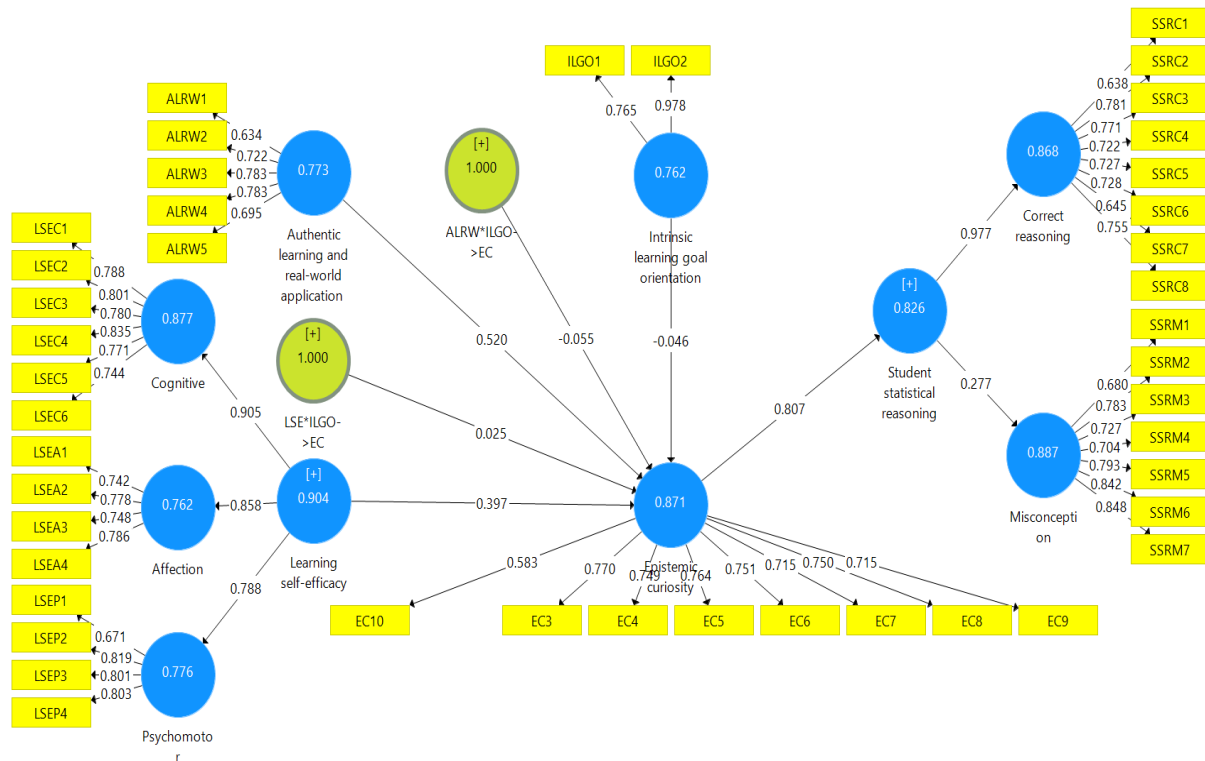


Figure 2: Estimated Model

Table 3 is a report of Heterotrait-Monotrait ratio of correlations (HTMT) that was applied to determine the discriminant validity between the study constructs. The use of HTMT criterion has been regarded as a more demanding and effective method of analyzing discriminant validity in PLS-SEM than the conventional techniques. Based on the recommended standards, the values of HTMT should be lower than 0.85 (or 0.90 in weaker combinations) so as to ensure sufficient discriminant validity. The findings reveal that most of the HTMT values are lower than the recommended value which means that the constructs are statistically different between each other. The acceptable inter-construct correlations are observed between constructs like authentic learning and real-world application, epistemic curiosity, learning self-efficacy, and student statistical reasoning with none of these being overly overlapping. The low HTMT values especially with intrinsic learning goal orientation are evidence of high discriminant validity of this construct which supports the conceptual distinctiveness of the construct in the model. Though a few of the correlations come close to higher values, particularly between conceptually related measures like learning self-efficacy, epistemic curiosity, and making correct judgments, they are within satisfactory levels of values. All in all, the HTMT findings confirm the existence of discriminant validity, which means that each construct measures a specific theoretical concept and therefore explains the reason why they should be included in the structural model at the same time.

Table 3 (a): Heterotrait-Monotrait Ratio of Correlations

	1	2	3	4	5	6	7	8	9	10
Affection										
Authentic Learning and Real-World Application	0.808									
Cognitive	0.796	0.790								
Correct Reasoning	0.811	0.760	0.779							

Table 3 (b): Heterotrait-Monotrait Ratio of Correlations

	1	2	3	4	5	6	7	8	9	10
Epistemic Curiosity	0.851	0.699	0.830	0.846						
Intrinsic Learning Goal Orientation	0.033	0.055	0.085	0.056	0.103					
Learning Self-Efficacy	0.314	0.896	0.839	0.844	0.892	0.085				
Misconception	0.114	0.129	0.085	0.112	0.085	0.769	0.107			
Psychomotor	0.778	0.660	0.650	0.688	0.721	0.107	0.855	0.100		
Student Statistical Reasoning	0.652	0.800	0.609	0.892	0.728	0.650	0.670	0.836	0.555	

Table 4 shows the effect size (f^2) and the explanatory power (R^2 and adjusted R^2) of the structural model, which gives an understanding about the power of the individual predictor effects and overall, the proportion of variance explained in endogenous constructs. The f^2 values reveal the extent to which each of the exogenous variables contributes to the exogenous variable. Authentic learning and intrinsic learning goal orientation interact with intrinsic learning goal orientation and learning self-efficacy had significant values of f^2 (0.569 and 0.422, respectively), which suggests that the moderating effects are substantial on epistemic curiosity. There are also direct effects which prove to have meaningful contribution where intrinsic learning goal orientation ($f^2 = 0.778$) and authentic learning and real-world application ($f^2 = 0.454$) have strong influence on epistemic curiosity. The effect sizes of learning self-efficacy are large on the affection and cognitive dimensions, yet another measure of its importance in the model. In terms of explanatory power, the predictors of epistemic curiosity have a high R^2 of 0.751 (adjusted $R^2 = 0.745$), which means that a significant percentage of the variance in epistemic curiosity is accounted by its predictors. student statistical reasoning has a high individual R^2 of 0.651 (adjusted $R^2 = 0.649$). These values are higher than the generally accepted ones, which validates the idea that the structural model has a high predictive power.

Table 4: F & R Square Fit statistics

Variable	F-Square						R-Square	
	Affection	Cognitive	Correct Reasoning	Epistemic Curiosity	Misconception	Psychomotor	Student Statistical Reasoning	R Square Adjusted
ALRW*ILGO->EC				0.569				
Authentic Learning and Real-World Application				0.454				
Epistemic Curiosity							1.862	0.751
Intrinsic Learning Goal Orientation				0.778				0.745
LSE*ILGO->EC				0.422				
Learning Self-Efficacy	2.795	4.551		0.266		1.640		
Student Statistical Reasoning			21.071		0.083			0.651
								0.649

Table 5 provides the model goodness-of-fit indices of the saturated and estimated models. The saturated model has a standardized root mean square residual value of 0.061 and an estimated model has a standardized root mean square residual value of 0.078 which is less than the recommended value of 0.08 thus it has a good fit. These values indicate that the difference between actual and expected correlations is small, which is an indication that the proposed model is sufficient. Moreover, the d ULS values of both models are within the acceptable ranges, which also prove the model fit. This is because the constraints on the structural paths would take the slightly higher values in the estimated model. All of that, together with these fit indices prove that the proposed research model shows an acceptable to good overall fit to the empirical data, which supports the belief in the strength of the measurement and structural model findings.

Table 5: Model Goodness of Fit Statistics

	Saturated Model	Estimated Model
SRMR	0.061	0.078
d ULS	5.049	5.983

Figure 3 presents the findings of the structural path analysis path coefficient, standard deviation, t statistic and p values of all the hypothesized relationships. The findings show that the six hypotheses are all statistically significant as their t-values and p-values are high and less than the 0.001 significance level. Authentic learning and real-world application have

6. Discussion

This discussion explains empirical results of the current study using current theoretical perspectives and previous theoretical studies with the ultimate aim being to enhance research literacy with the aid of biostatistics education. Through the empirical validation of the proposed research model, the study provides a deeper insight into the way the instructional design factors and motivation belief interplay with the cognitive-motivational processes to determine the effect on epistemic curiosity and student statistical reasoning. The fact that all six hypotheses are accepted gives good evidence of the built-in framework and emphasizes epistemic curiosity as an effect of both instructional and motivational factors along with the process connecting genuine learning and learning self-efficacy to a higher order of reasoning. Discussed below within the framework of contemporary discussions on authentic learning, motivation and data-informed pedagogy, these findings are presented in terms of direct effects, moderating influences and mediating mechanisms.

The fact that the first hypothesis is accepted proves that the authentic learning and real-world application are important factors in improving epistemic curiosity in learning biostatistics. This observation is consistent with previous studies that have shown that exposure to real-world tasks, applied datasets, and open-ended analytical problems incur cognitive disequilibrium that inspires learners to become aware of knowledge gaps and become inquired (Akgün et al., 2022; Nachtigall & Firstein, 2024). The genuine learning settings present students with uncertainty, partial information, and situationally-specific meanings, which are fundamentally curiosity-inducing and key features of epistemic interaction (Batdi, 2023). The open biostatistical data used in the current research probably increased the awareness of the students about the complexity and non-linearity of the actual research process and the desire to engage in exploratory behaviours and hold intellectual curiosity. The results are a continuation of prior studies, which empirically validates the role of authentic learning in promoting epistemic curiosity in a context with biostatistics education, which is frequently accused of teaching too much procedural knowledge at the cost of inquiry (Bromage et al., 2022; Tanus et al., 2025).

The evidence in favor of the second hypothesis suggests that the learning self-efficacy having the significant positive impact on epistemic curiosity. This finding aligns with the Social Cognitive Theory, which argues that the beliefs regarding learner capabilities define his or her readiness to work on difficult tasks and unknown problems (Gobinath et al., 2024; Kang et al., 2019). Higher learning self-efficacy students in data-intensive learning conditions will tend to respond to complex datasets and data processing tasks with confidence, but not avoidance, which establishes psychological states that support exploration and questioning (Follmer, 2023). Previous research found that self-efficacy decreases anxiety and increases persistence in quantitative learning, which indirectly provides benefits to curiosity-motivated behaviors (Naveed et al., 2024; Shin, 2024). The current results are relevant to the literature because they place epistemic curiosity as a motivational product of self-efficacy learning where a void exists in the empirical literature with curiosity often ignored in place of performance products (Tanus et al., 2025).

The third hypothesis, which is the moderating influence of the intrinsic learning goal orientation in the connection between authentic learning and epistemic curiosity, offers valuable information as regards the conditionality of the instruction effectiveness. The results indicate that the authentic learning condition is especially useful to arouse curiosity in learners with the intrinsic perspectives on mastery and understanding. To such students, the real-world practice is encountered as an exploration, intellectual development process instead of a forced process required by an external entity. This finding corresponds to the Self-Determination Theory, which states that autonomy-supportive and meaningful learning experiences have a more positive effect on intrinsically motivated learners (Benbassat, 2024; Peters et al., 2022). According to the moderation effect, authenticity does not have the sufficient impact to ensure epistemic curiosity but that its effects increase when learners have powerful intrinsic learning goal orientation. This result makes the contribution of the previous studies because it empirically shows the role of learner motivation in determining the effectiveness of authentic instructional design.

Equally, the fact that the fourth hypothesis is accepted supports the fact that intrinsic learning goal orientation mediates the relationship between learning self-efficacy and epistemic curiosity. Although self-efficacy learning offers the confidence to take part in hard statistical activities, intrinsic learning goal orientation seems to be the reason why this confidence is focused on exploration and inquiry or on task completing. Students who have high intrinsic goal orientation tend to utilize more their perceived competence to pose questions, explore trends, and gain greater insight of statistical phenomenon. This result is in line with motivational interaction theories that claim that competence beliefs and goal orientations co-determine learning behaviors (Taylor et al., 2023; Yañez et al., 2023). It also contributes to understanding inconsistency with other prior studies on effects of self-efficacy, which is that self-efficacy does not consistently lead to curiosity in the absence of supportive motivational orientations.

The fifth hypothesis proved that epistemic curiosity is what mediate between authentic learning and the authentic learning and real-world application and student statistical reasoning. According to this mediation, authentic learning improves statistical reasoning in an indirect way by arousing curiosity initially. Real-world data exposure presents ill-formulated problems and meaningful uncertainty, which prompts epistemic curiosity and increases analytical processing

and interpretation of statistical evidence. The result concurs with the constructivist and cognitive engagement approaches, which claim that higher-order reasoning is constructed based on inquiry instead of passive exposure to information (Batdi, 2023; Dehyouri et al., 2011). The study can fill a very important gap in the research of statistics education, in which the processes that connect instructional design and reasoning outcomes have been largely conjectural.

The sixth hypothesis is an extension of this mechanism demonstrating that epistemic curiosity mediates between learning self-efficacy and student statistical reasoning. These findings show that self-efficacy plays a role in enhanced reasoning especially where there is a curiosity-based engagement. When coupled with epistemic curiosity, learners who hold a belief in their analytical abilities tend to investigate data, challenge findings and consider alternative methodological solutions. This result confirms previous studies which indicate that confidence is not enough to realize deep learning and that curiosity is the motivational agent that converts beliefs into meaningful cognitive performance (Ignjatović & Stevanović, 2023; Naveed et al., 2024). The study has a more detailed explanation of the effects of self-efficacy on the statistical reasoning process by integrating the motivational and cognitive perspectives with an epistemic process.

Altogether, the results give good empirical evidence of an integrated framework in connecting authentic learning and real-world application, learning self-efficacy, intrinsic learning goal orientation, epistemic curiosity, and student statistical reasoning. The results highlight epistemic curiosity as a central mechanism through which instructional design and motivational beliefs shape higher-order reasoning. This integrated perspective advances theoretical understanding, clarifies previously inconsistent findings, and offers practical guidance for designing authentic, curiosity-driven biostatistics learning environments that promote research literacy.

6.1 Implications

The study has a number of significant theoretical contributions through its contribution to an integrated explanatory framework that relates instructional design, motivational beliefs, and cognitive-motivational mechanisms to biostatistics education. To begin with, the research augments the Social Cognitive Theory by showing that the learning self-efficacy does not only predict the performance-related outcomes but also serves as an antecedent to the epistemic curiosity, hence contributing to the body of knowledge on the role of the competence beliefs in shaping the epistemic orientations. Second, using Self-Determination Theory, the results validate that the moderating role of intrinsic learning goal orientation is very crucial, as it has a stronger influence on curiosity between authentic learning and self-efficacy, which emphasizes motivation process conditionality. Third, the paper contributes to the Epistemic Curiosity Theory whereby curiosity is placed at the center as a mediating factor where instructional authenticity and self-efficacy are translated to higher-order statistical reasoning. The study seals gaps between discontinuous sections of the literature and provides a more detailed theoretical account of the development of research literacy in data-intensive learning settings through the empirical validation of a moderated mediation model in a biostatistics context based on the open datasets.

The recommendations of this paper provide practical information to teachers, curriculum developers, and higher education institutions who want to improve the teaching of biostatistics and data science. What is shown in terms of the significance of authentic learning and real-world application is that instructors ought to systematically incorporate open datasets, real research issues, and applied analysis activities into their instructional activities. These methods have the potential to activate epistemic interest and evoke a greater interest in statistical ideas. Also, the high importance of the learning self-efficacy implies the necessity of instructional techniques that support both the confidence of students, including scaffold learning, formative feedback, and mastery experience opportunities. The moderating role of the intrinsic learning goal orientation also suggests that the educators must create the mastery-oriented learning environments in which learning is based on meaning and questioning as opposed to memorization. At the institutional level, the findings justify institutional policies that facilitate the availability of open educational resources and access to data, since these do not only ease the learning process but also add meaningfully and sustainably to the capability of students to find, research, and think critically.

6.2 Limitations and Future Research Directions

Lasting as much as it has contributed, this study has numerous limitations that must be put in mind when explaining the findings and future research. To begin with, cross-sectional research design does not allow causal conclusion to be made on cross-relationship between constructs. Longitudinal or experimental designs would give greater support to the time sequence and causation processes. Second, the focus on self-reported measures can add the common method bias and social desirability effects implying that future researches can include objective performance measures or a behavioral measure of curiosity and reasoning. Third, the research was carried out in a certain educational and disciplinary environment, and it could restrict the extrapolation of the results to other spheres or cultural backgrounds. The model needs to be deployed in other fields, educational levels and institutions in future studies. Moreover, alternative moderators, including preceding statistical knowledge or digital literacy, and the effects of epistemic curiosity on research output and professional competence in the long run, can be investigated in the future.

7. Conclusion

This research proposed to investigate the relationship between authentic learning and real-life practice, learning self-efficacy, and intrinsic learning goal orientation to influence the development of epistemic curiosity and student statistical reasoning in teaching biostatistics. The empirical evidence is highly supportive of the suggested model and it shows that, authentic instructional practices and motivational beliefs held by learners have a significant impact on epistemic curiosity that, in its turn, is one of the primary mechanisms that lead to higher-order reasoning performance. The study provides a subtle view on how instructional and motivational factors interact to promote the development of research literacy by confirming the moderating, as well as the mediating relationship. These findings highlight the fact that valuable learning in the area of biostatistics is not merely a procedural competence process but rather involves enquiring curiosity and critical thinking. Finally, the study also notes the radical possibility of using open datasets and real-world learning settings to achieve epistemic curiosity and sound statistical thinking in learners. The study contributes to theory and practice of data-driven education by combining theoretical insights of the Social Cognitive Theory, Self-Determination Theory, and Epistemic Curiosity Theory. The conclusions represent great tips to teachers, policy-makers who are interested in creating learning environments that should not only teach technical skills but should also create curious, self-confident and analytically minded learners. Eventually, this study can be added to the cumulative set of studies that promote learner-centered, authentic, and motivation sensitive methods of teaching biostatistics and acquiring research literacy.

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