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The Moderated Mediation of Technology-Driven Pedagogical Process and Collaborative Learning to Instructional Efficiency and Students' Learning Engagement in Statistics

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Abstract. This study undertakes the influence of technology-driven pedagogical processes and collaborative learning on instructional efficiency and undergraduate students' learning engagement in statistics. The premise of the study is anchored to the commonly held notion that learning math and math-related subjects is difficult for students, especially if they are not inclined toward numeracy. This research was conducted among junior undergraduate students who are currently taking up a course in statistics for the academic year 2023-2024 at the time of writing this research. This study was conducted to conduct a cross-sectional assessment of the overarching goal, as stated in the title of this research paper. Hayes PROCESS model 58 was used to analyze the interplay of the parameters and to verify the supposition of the study. The results of the study suggest towards the affirmation of the supposition. Technology plays a crucial role in the learning process of modern-day undergraduate students, thereby enhancing their level of learning engagement. Instructional efficiency remains a major consideration in pedagogical processes. Collaborative learning, one of the four tenets of Education 4.0, is a vital ingredient in amplifying the learning process and enhancing the level of learning engagement.

Keywords: *technology-driven instructional process, technology usage, collaborative learning, instructional efficiency, learning engagement*

INTRODUCTION

Education in the twenty-first century has dramatically shifted in form and pedagogical processes. Swift and unprecedented adoption of enabling technologies for the teaching-learning process have brought about a dramatic paradigm shift in the world of education. Social disruptions (Stoian et al., 2022) and the ripe time of shifting to a more technology-driven educational process (Schleicher, 2018; Trust et al., 2020) are among the major drivers of change in education. Digitally transformed educational processes are indeed necessary in response to the mandate and challenges of Education 4.0 (Oliveira & de Souza, 2022). Educational leaders and teachers alike must recon the fact that there is a need to transcend the old educational paradigm into a digitally enabled environment to suit the demands of the current teaching-learning situation (McCarthy et al., 2023). Technology-driven instructional processes have the potential to enhance students' learning engagement, eventually leading to better academic performance. Along with other parameters such as instructional efficiency

and a learning environment that fosters collaborative learning, transcending the current educational system can be achieved.

The Role of Technology in Instruction and Knowledge Construction

Closing the 'gap' between students' conventional learning and development at school and 'the experiences and skills that our youth need to enter the information economy' has heightened the demand for technology-driven instructional processes (Kozma, 2011). At this juncture, the school curriculum should progressively be interconnected and interwoven with ICT. The rationale behind this educational movement is for students to be given opportunities to use advanced technological tools and digital resources for creative and innovative problem solving (Kozma, 2011).

Moreover, technology helps teachers design their lesson plans in an effective, creative, and interesting manner that would result in students' active learning. Previous researchers have proven that the use of ICT in teaching will enhance the learning process and maximize students' abilities in active learning (Finger & Trinidad, 2002; Jorge et al., 2003; Young, 2003). Technology-based teaching offers many interesting approaches to teaching, including educational videos, stimulation, storage of data, usage of databases, mind-mapping, guided discovery, brainstorming, music, and the World Wide Web, which will make the learning process more fulfilling and meaningful (Finger & Trinidad, 2002).

The advocates of cognitive development applied to students' learning and professional development have espoused the significance of ICT (Fu, 2013; Simin & Rosdy, 2015; Infante-Moro et al, 2019) in education. The proper use of ICT in the teaching-learning process has a significant impact on enhancing the quality of education, thus fostering active and collaborative learning over traditional methods (Amutha, 2020).

Cognitive development to enhance students' capabilities in creative thinking, information analysis, and problem solving through computer-assisted instruction has been found to be effective (Haleem et al., 2022). ICT should provide students with a variety of learning scenarios in vast spaces to construct their knowledge. If used properly in education, ICT can offer a myriad of appropriate learning strategies to students in a specific context. The recent shift of greater ICT involvement in education has significantly ushered in network and interactive technologies being widely applied in pedagogical processes. Further, the technological competence of teachers and their ability to impart content knowledge assisted by enabling technologies have a significant effect on students' assimilation, competence, and performance.

Instructional Efficiency and Learning Engagement

In this research, engagement is contextualized to the degree of positive outlook and involvement of a student towards school and academic activities. Barkley and Major (2020) suggest that students' learning engagement is related to the intersection of their feelings and cognitive functions. Students' learning engagement is tied to their academic success (Ali & Hassan, 2018). There are various factors that affect students' learning engagement, ranging

from cognitive to affective (Amerstorfer & Munster-Kistner, 2021). Moreover, educational technology affects students' engagement in some manner affect students' engagement (Bond & Bedenlier, 2019). At the outset, teachers also play a very important role in sustaining students' learning engagement with their motivational support (Cents-Boonstra et al., 2019). Going further in the topic of engagement is the need for a conducive learning environment that encourages students to actively participate, regardless of the learning modality (Shernoff et al, 2016).

Conceptual Framework

Empirical studies have established and verified causal relationships among causal phenomena and situations that have unified or varied effects. It aims to answer the question of whether the effects do happen and are causal in nature, the sequence of events in terms of intensity, existence or lack of significant impact, the direction and magnitude that depend heavily on the nature of the context, and individual differences. A complete analysis of a phenomenon reveals most of the causal relationship effects. (Hayes & Preacher, 2013). Thus, to establish a causal link between and among observable variables, structural equation modelling (SEM) was used under confirmatory factor analysis. Figure 1 shows the causal relationships between the latent constructs of this study. SEM begins with a theory as a starting point to test the relationship between the constructs of interest in the study (Thakkar, 2020). The relationships are modeled into a structural framework represented by the schematic diagram depicted in Figure 1, in which the hypotheses of this study have been aligned.

Objective and Hypotheses

This research was anchored on the premise that there is a moderated mediation of technology-driven pedagogical processes and collaborative learning on instructional efficiency and students' learning engagement in statistics courses.

There are two (2) overarching hypotheses for this study: (1) the first is to validate whether there is a direct effect between instructional efficiency and students' learning engagement, and (2) to verify the moderated mediation effect of technology-driven pedagogical processes and collaborative learning on instructional efficiency and students' learning engagement.

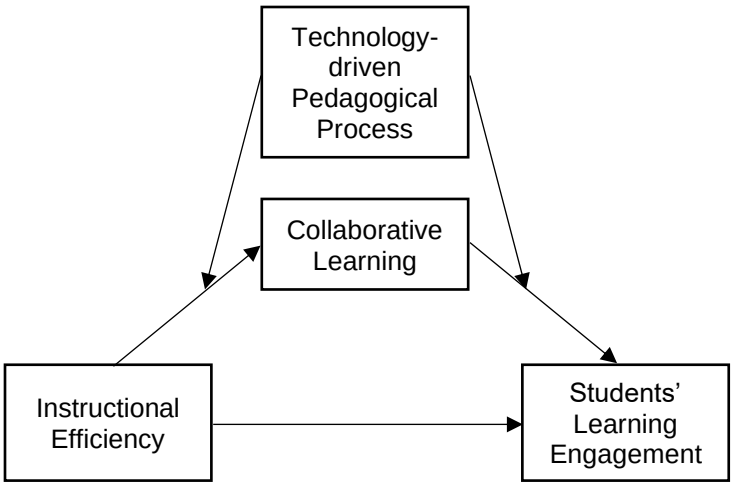

Figure 1. *Conceptual Diagram of the Study*

METHODS

This research utilizes the conditional process approach to understand the mechanisms by which an effect operates through mediation analysis to understand the contingencies or boundary conditions of the effects. How the effects operate (i.e., the mechanism at work) and their boundary conditions (when they occur) are not necessarily independent, although they are often treated as in the case of this study. Conditional process analysis is an analytical strategy that integrates mediation and moderation analyses to examine and test hypotheses about how mechanisms vary as a function of context (Hayes & Rockwood, 2019).

The rationale behind the choice to use conditional process modeling is that the treatment of data requires an analytic analysis of mediation and moderation. Mediation analysis reveals the underlying reason for the explanation of the causal effect. It is an appropriate model or approach to determine the causal processes between a predictor and outcome. Moderation analysis, on the other hand, examines whether the impact of a predictor in the form of outcome varies given different situations and conditions. Conditional process models (also referred to as moderated mediation models or mediated moderation models) are an integration of mediation and moderation, which are appropriate in determining how predictors and outcomes differ in terms of the individual identity of a given context (Bachl, 2017).

The conditional process approach model (Model 58) using the Hayes Process Macro embedded within the SPSS program was utilized for this structural equation modelling study. Hayes' Process Macro is a structural equation model that utilizes a regression-based approach to verify causality among the variables under consideration. The Hayes Process Macro enables research to perform procedures for testing and describing research propositions about the phenomena in which the predictor affects the outcome, the situations in which these happened, and the moderation of mechanisms. Hayes Process Macro

explains the probable effect directly and indirectly, discusses the interaction effects, and proves the inferential queries about moderated mediation by relying on the principles of ordinary least squares regression (Hayes, 2013). Figure 2 shows a statistical diagram of the study.

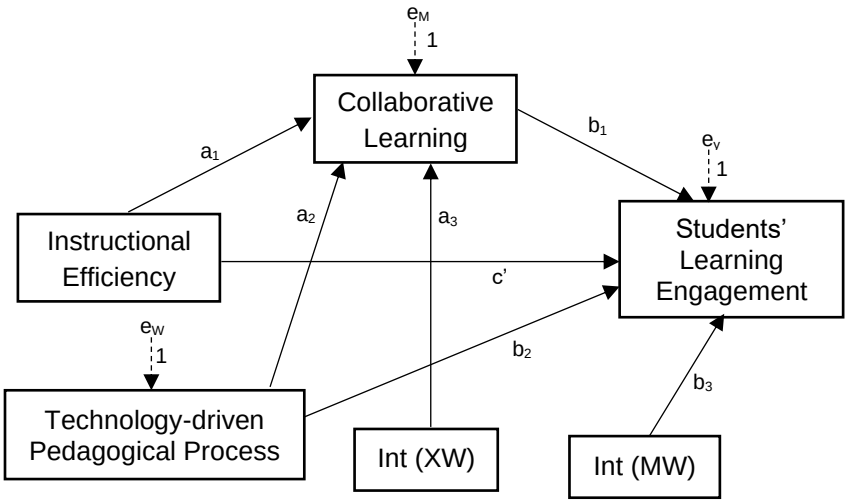

Figure 2. *Statistical Diagram for Moderated Mediation of Technology-Driven Pedagogical Process and Collaborative Learning to Instructional Efficiency and Students' Learning Engagement in Statistics*

Respondents of the Study

The respondents in this study were junior college students from a local state college enrolled in a statistical course. The respondents were in the business track discipline. All respondents were given the opportunity to utilize instructional technology tools for problem-solving using statistical software. With a total of 191 junior college students taking the statistics course at the time of writing, 173 respondents returned the survey form.

Sufficiency of sample size. The existing body of literature on sample size determination for SEM suggests that n=100-150 would be a considerable number for the lower bound limit (Tabachnick and Fidell, 2001) although some researchers offer to round it to n=200 (Boomsma and Hoogland, 2001; Kline, 2005). Simulation studies show that with normally distributed indicator variables and no missing data, a reasonable sample size for a simple confirmatory factor analysis (CFA) model is about n = 150 (Muthén and Muthén, 2002).

Instrument

The research instrument was developed by researchers utilizing previous literature as a basis for constructing the indicators of the latent constructs. The research instrument can be found in the last part of this paper in the appendix. Following the completion of the research instrument, it was subjected to reliability testing with 20 pilot respondents (Fink, 2013; Saunders et al., 2016).

Cronbach's alpha reliability index yielded the following results for the research instrument parameters, as shown in Table 1. To wit;

Table 1. *Reliability Test Results*

Parameters	No. of Items	Cronbach's Alpha
Instructional Efficiency	5	0.92
Collaborative Learning	5	0.94
Technology-driven pedagogical process	5	0.94
Students' learning engagement	5	0.93

The result for Harman's single factor test was 31.23% indicating that there was a manageable common method bias produced by the research instrument.

RESULTS

There was a direct effect between instructional efficiency and students' learning engagement, as indicated by the beta coefficient of 0.3367, with a very high p-value of 0.0000, otherwise known to be 99% significant. Thus, the research hypothesis was valid for this study. Instructional efficiency has a significant positive effect toward students' learning engagement.

Table 2. *Direct Effect of Instructional Efficiency to Students' Learning*

Parameters	β	95% CI	p-value	Int
Direct effect of instructional efficiency to students' learning engagement	0.3367	0.1982, 0.4753	0.0000	Significant direct effect

Table 3 shows the moderated mediation analysis using pairwise contrasts and their corresponding confidence intervals. All confidence intervals are significant at the 95% level because the confidence intervals have no presence of zero. The model summary of R2= 0.86, with a p-value of 0.000, suggests that the model is significant at the 99% confidence level. The model had a predictive power of at least 86%, and the remaining residual was attributable to unexplained variance. Thus, the research hypothesis is valid for this study. There exists a moderated mediation effect of technology-driven pedagogical processes and collaborative learning on instructional efficiency and students' learning engagement.

Table 3. *Moderated Mediation (Pairwise Contrasts-Effect 1 minus Effect 2) Analysis*

Effect 1	Effect 2	Contrast	95% CI	Int
0.1104	0.1546	-0.0442	-0.0707, -0.0252	Significant; Non-Zero CI
0.0804	0.1546	-0.0742	-0.1170, -0.0425	Significant; Non-Zero CI
0.0804	0.1104	-0.0300	-0.0470, -0.0172	Significant; Non-Zero CI
Model Summary: R2= 0.86, p=0.0000				

Figure 3 shows the structural model for the study with the corresponding path coefficients for the direct and indirect effects. Moderated mediation coefficients of -0.0653 (p=0.0042) and -0.0565 (p=0.0189) were significant. Thus, there is moderated mediation of this structural model.

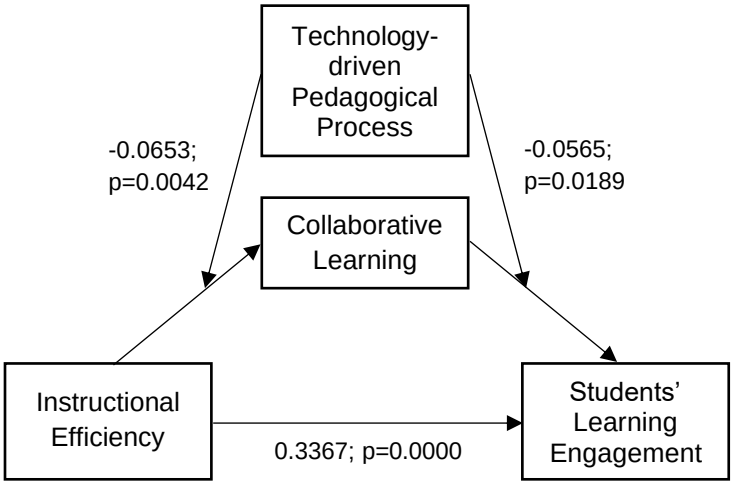

Figure 3. *Structural Model of the Study*

DISCUSSION

The aforementioned results from the empirical investigation suggest the existence of moderated mediation for technology-driven pedagogical processes and collaborative learning on instructional efficiency and students' learning engagement. The result will only go as long as the parameters are well placed inside the learning environment. The synergy of all constructs necessary for the realization of the aforementioned results is the main reason for the validity of the research hypotheses. It can be assumed that if one construct is rated low, the results may be different.

Based on the empirical results of the study, students posted high-rating responses for all constructs, thus resulting in a positive effect for the structural model. From the respondents' perspective, technology-driven pedagogical processes, along with encouragement for collaborative learning, have been meaningful at their end. The utilization of enabling technologies to learn statistics, as in the case of using statistical software, has been well received by students.

Learning is more meaningful when students are able to interact with themselves aided by educational technology. The process of interaction and collaboration among students plays a vital role in enhancing their cognitive ability, along with knowledge construction and assimilation of concepts. It is important for teachers of higher education institutions to manifest instructional efficiency along with proper utilization of instructional technology in order to realize the end goal of the authentic teaching-learning process. Engaging students to interact, collaborate, and exercise critical thinking will enable their cognitive development

to develop further. This academic preparation and training are vital for students' development, which is necessary for them to become adaptive and mentally ready to enter the workplace once they finish college.

In the context of learning statistics and math-related subjects, educators are expected to teach and engage students within the framework and environment of clarity and precision. One very important factor that must be considered for students to participate, engage, and collaborate with each other is the learning environment that encourages fairness and equal opportunity for all students regardless of their cognitive dexterity.

It will be more meaningful for students to learn if they are properly engaged, provided that the conditions for learning are well placed by teachers. Such well-placed conditions would require teachers to be fully adept in the subjects they are teaching, along with the utilization of excellent learning resources, which is at par with the world's best. The use of technology in the teaching-learning process will further enhance the level of learning among students, provided the teacher is well equipped with the right pedagogical skills to impart the necessary knowledge to students.

Conclusion

Motivating students to learn and fully engage in their studies is not an easy task for teachers of higher education institutions, especially in math and quantitative subjects. Creativeness and the skillful transfer of knowledge from teachers to students are necessary for the quality of the pedagogical process. Instructional efficiency entails teachers' readiness, skillfulness, and adeptness for the subject matter. These are necessary ingredients for authentic knowledge transfer. With the advent of new realities, unfolding within the world of education, new educational technologies and learning modalities have to be embraced by both teachers and students. The use of modern technologies in pedagogical processes has much to do. In the field of statistics and math-related disciplines, there are numerous enabling educational technologies that can be utilized to increase students' engagement and appreciation towards the subject. It should be harnessed and utilized properly to improve the teaching–learning process.

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