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RESEARCH ARTICLE

Exploring Statistical Literacy Deficiencies and Causal Associations among Master and Doctoral Graduates in Thailand

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ABSTRACT

Statistical literacy deficiencies and factors affecting statistical literacy allow teachers to emphasize, add, or modify learning activities to achieve expected outcomes. Hence, this study investigated statistical literacy deficiencies and examined causal relationships in statistical literacy among master and doctoral graduates in Thailand. The study employed convenience sampling to include 90 participants, including master and doctoral graduates in Thailand. Data were collected by a statistical literacy test and a 5-point Likert scale estimator questionnaire based on five factors, including achievement motivation, experience in statistics, learning attitudes, self-efficacy, and teaching practices. Findings revealed that the participants' statistical literacy was transitional overall. However, their literacy skills, mathematical knowledge, and statistical knowledge were either analytical or quantitative. Furthermore, experience in statistics was the only factor directly affecting statistical literacy. The findings confirmed that it is vital for teachers to formulate their pedagogies to promote skill internalization and provide experiences for future application.

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INTRODUCTION

Higher education institutions in Thailand annually produce a large number of master and doctoral graduates, spreading across industries nationwide. In addition to field expertise, master and doctoral graduates are expected to possess adequate statistical knowledge to conduct research, plan for data management, and present information. Statistical literacy (SL) research in Thailand remains relatively scarce, with few studies available. Notably, Yotongyos (2013) and Torteeka (2020) conducted research on undergraduate students, while Che-ha (2020) focused on Secondary 3 students. However, these studies primarily presented the level of SL within their respective samples, without conducting in-depth analyses or identifying potential flaws in SL. As a result, the application of this limited knowledge raises practical concerns about the potential for errors and misinterpretations, especially when examining differences among groups of graduates. Exploring the concept of SL, as described by Gal (2002), it represents the ability to understand and assess statistical data and data-driven reasons from sources of information and media as well as the ability to explain ideas based on statistical data. SL comprises two elements. The first element is knowledge with sub-components including 1) literacy skills, 2) statistical knowledge, 3) mathematical knowledge, 4) context knowledge, and 5) critical questions. The second element is disposition with sub-components of 1) beliefs and attitudes and 2) critical stance.

Most studies on SL congruently suggested that even though their participants had high literacy skills, statistical knowledge, and mathematical knowledge, their context knowledge and critical questions were low. For instance, Yotongyos (2013) indicated that undergraduate students in Thailand had extremely high literacy skills and statistical knowledge, followed by mathematical knowledge, context knowledge, and critical questions, respectively. According to Torteeka (2020), undergraduate students in Thailand exhibited strong literacy skills, moderate proficiency in statistical and mathematical knowledge, but showed limitations in context knowledge and critical questioning abilities. Che-ha (2020) investigated the SL of Secondary 3 students in Thailand and stated that their literacy skills had the highest mean score, followed by mathematical knowledge, statistical knowledge, and context knowledge, respectively. Besides, Cimpoeru and Roman (2018) explored the SL of students in Romania and reported that literacy skills had the highest mean score, followed by statistical knowledge and mathematical knowledge, respectively. Moreover, Berndt et al. (2021) published a vital piece of information that undergraduate and graduate students in Social Sciences in Germany had lower SL scores than those in Medicine and Economics. Evidently, Jenny et al. (2018) conducted a comparative analysis of two participant groups, including 169 students and 16 senior educators in Germany, and revealed that the two groups had significantly different mean SL, but both mean scores reflected that the two groups did not possess the fundamental knowledge of statistics.

Certain factors are closely associated with SL. Notably, experience in statistics ranked second, following achievement motivation, in terms of its impact on SL, as indicated by Che-ha (2020). For students, experience in statistics emerged as the most direct and positive factor influencing SL, as found in studies conducted by Yotongyos (2013) and Torteeka (2020). Furthermore, existing mathematical, statistical, and computing experiences were found to be correlated with assessment outcomes in Statistics, as observed by Dempster and McCorrey (2009). Hence, Experience in statistics encompasses the learning process of encountering diverse situations, be it through printed media, social media, or in statistics classrooms where instructors impart knowledge. Such experiences enable learners to adapt and enhance their cognitive abilities by actively engaging with numerical and statistical information.

Another significant factor is achievement motivation, which drives learners to study and learn. This motivation can arise from the desire to apply knowledge in professional or real-life contexts. Conversely, it may also be influenced by negative emotions towards a specific subject or lesson, especially if it is perceived as difficult, leading to a reluctance to engage in learning. Che-ha (2020) identified achievement motivation as the foremost factor influencing SL. Moreover, in Turkey, Yurt (2015) found that intrinsic motivation played a crucial role in predicting mathematics achievements among students, demonstrating direct and indirect interrelatedness. Additionally, Khamta (2015) showed that achievement motivation significantly affected the statistical achievement of undergraduate students in Thailand.

Learning attitudes represent another influential factor that impacts SL, as evidenced in the research by Cimpoeru and Roman (2018). These attitudes also influence students' perceptions of studying statistics, as demonstrated among Thai and Chinese students in Thailand by Torteeka (2014). Notably, attitudes toward mathematics play a crucial role in promoting individual academic achievements, as revealed by Damrongpanit (2019). Moreover, attitudes toward statistics courses have shown a positive correlation with self-efficacy, as indicated by Perepiczka et al. (2011), while both mathematical skills and attitudes toward statistics are believed to influence statistics education, as suggested by Zieffler et al. (2008). Consequently, learners' attitudes toward learning, their inclination or reluctance to engage in the learning process, significantly impact their willingness to learn in specific lessons or situations. Possessing a positive attitude or adapting attitudes to foster favorable emotions can lead to a smoother and more effective learning experience in the specified lessons.

Self-efficacy emerged as another influential factor contributing to SL, as revealed in Carmichael et al. (2010). The perception of self-efficacy revolves around a person's belief in their ability to accomplish or learn what is defined or not. This belief can influence their decision to take certain actions, which may sometimes be driven by emotions or thoughts in a given situation. Evidently, the multifaceted teaching framework demonstrated positive impacts as it reduced statistical anxiety and enhanced statistical self-efficacy (McGrath et al., 2015). In addition, mathematics self-efficacy was identified as a predictor of cognitive results such as PISA scores in mathematics, also categorized as a mathematics achievement (Karakolidis et al., 2016; Kalaycioglu, 2015; Mundia & Metussin, 2019; Nasir et al., 2014; Romero-Carazas et al., 2024; Pratiwi et al., 2024).

Although teaching behavior has not been found to directly impact SL in existing research, it has demonstrated its influence on academic achievement and attitudes, as shown in Frome et al. (2005) and Che-ha (2020). Teaching practices involve organizing learning activities both inside and outside the classroom to enable learners to acquire knowledge and understanding applicable in their daily lives. An engaging and positive teaching behavior can lead to remarkable results, as it fosters students' interest and enthusiasm for the subject. Conversely, if teaching behavior is perceived as dull or uninteresting, it may create a barrier, causing students to lose interest and become disengaged from the subject matter.

The results of the aforementioned research underscore the impact of all five factors (achievement motivation, experience in statistics, learning attitudes, self-efficacy, and teaching practices) on SL, as evident in the samples of both Thai and international students. This study holds significant value as a guiding reference for graduate-level teaching and learning, applicable in both local and international contexts. By identifying the influential factors impacting learning outcomes, educators can effectively direct their efforts towards achieving institutional expectations.

Purpose of the study

1. To analyze and identify SL deficiencies observable among master and doctoral graduates in Thailand
2. To assess and contrast SL scores among various different educational levels in the fields of Research and Statistics and other fields
3. To explore the causal relationship in SL among master and doctoral graduates in Thailand

LITERATURE REVIEW

Teaching statistics in Thailand

In Thailand, Mathematics education contains three core learning strands, including Numbers and Algebra, Measurements and Geometry, and Statistics and Probability. According to the Statistics and Probability strand, graduating Secondary 6 students are expected to meet the following requirements. 1) They must understand the statistics required for presenting, analyzing, and interpreting data related to dot plots, stem and leaf plots, histograms, central tendency, and box plots. 2) They must understand probability and be able to use the knowledge to solve problems in real life. 3) They must understand and be able to apply the principles of basic counting, permutation, combination, and probability when solving problems. 4) They must understand and be able to use statistical knowledge to analyze, present, and interpret data for decision-making (Ministry of Education, 2017).

In higher education, some undergraduate students in Thailand will be required to take at least one fundamental statistics course, where they will revisit the content of previous SL learned at the secondary level and study additional reference statistics, such as chi-squared test, correlation test, the test of differences in proportions, mean, and variance. However, those in humanities programs might not be required to take a statistics course. Instead, they might be required to take mathematics courses that revisit some elements learned in secondary education and additional mathematical topics that are commonly encountered in everyday life such as interests, polls, and opinion surveys. Furthermore, additional statistics courses, such as nonparametric statistics, analysis of variance (ANOVA), regression analysis, and multivariate analysis might be included in some master and doctoral programs, with the depth of content depending on fields and specialization.

Therefore, conducting an analysis and identifying potential weaknesses in the SL of Master's and doctoral degree holders is essential. This result can shed light on areas where individuals may still require improvement. Specifically, the study can categorize SL based on different fields of study, allowing for comparisons to determine if graduates from research-intensive fields perform better than those from other domains, as perceived by instructors. Such valuable insights can inform necessary changes in teaching and learning strategies tailored to specific fields.

Achievement motivation

Motivation is defined as the desire to associate with a specific matter, reflecting an individual's aspiration, purposes, and definition of success (Damrongpanit 2019; Tambunan, 2018; Pintrich & Schunk; 2002). Che-ha (2020)'s study is the only research that has identified a connection between achievement motivation and SL. However, in most cases, achievement motivation has been found to influence academic performance in both statistics and mathematics, as evidenced by studies conducted by Khamta (2015) and Yurt (2015). Furthermore, Nakpajon and Makanong (2022) found that motivation in learning science and self-efficacy in science affected scientific literacy among Secondary 3 students. Hence, investigating the potential influence of achievement motivation on SL among graduates can offer valuable insights into understanding the causal relationships between these factors.

Experience in statistics

Experience in statistics refers to individuals' learning, adaptation, and application in daily life upon receiving statistical information (Che-ha, 2020). The findings of all three studies (Yotongyos, 2013; Torteeka, 2020; Che-ha, 2020) underscore the substantial impact of experience with statistics on SL. Additionally, McGrath (2015) also revealed that statistical experience influences an individual's self-efficacy and concern related to statistical anxiety. Furthermore, Zieffler et al. (2008) found that gender, prior knowledge, mathematical skills, and attitude towards statistics were factors affecting teaching and learning statistics. Therefore, it is of utmost importance to examine whether statistical experience impacts SL among graduates. This research will offer additional validation of the substantial role statistical experience plays in the learning process of statistics and its direct connection to attaining SL. Moreover, it will explore whether statistical experience also influences self-efficacy, as indicated in previous research.

Learning attitudes

Attitudes are a psychological construct regulating responses and decisions concerning other beings, objects, places, concepts, and events. Since attitudes develop from learning and evaluation, they are not a passive product of previous experience but an originator of behaviors (Moenikia & Zahad-Babelan, 2010). Cimpoeru and Roman (2018)'s study is the only research that has identified a connection between learning attitudes and SL. According to Che-ha (2020), learning attitudes ranked third in significance to SL, following achievement motivation and experience in statistics. However, Positive attitudes towards statistics were associated with higher cognitive competence and appreciation for the subject, according to Lateh (2018). Students who found statistics courses challenging but interesting demonstrated greater commitment to their studies. Torteeka (2014) revealed that learning environments and attitudes influenced how Thai and Chinese students perceived statistics in Thailand. Judi et al. (2011) found that optimistic Malaysian learners exhibited commitment, enjoyment, and eagerness to learn statistics, along with a belief in their ability to apply their knowledge in the future. Hence, it is essential to investigate whether learning attitudes will impact SL among graduates. This study will provide further evidence of the significant role attitudes play in determining learners' SL, establishing it as a crucial factor in achieving SL.

Self-efficacy

Self-efficacy refers to an individual's judgment and perception of their ability to handle challenges toward desired goals (Bandura, 1986). Carmichael et al (2010)'s study is the only research that has identified a connection between self-efficacy and SL. Besides, Karakolidis et al. (2016) and Kalaycioglu (2015) also indicated that mathematics self-efficacy is can serve as a predictor of cognitive performance such as PISA scores in mathematics in the contexts of England, Greece, Hong Kong, the Netherlands, Turkey, and the USA. Mundia and Metussin (2019) demonstrated that participants in Brunei with sufficient self-efficacy were able to autonomously develop their learning skills and the ability to employ effective learning strategies for enhancing their mathematical learning and achievements. Consequently, it is crucial to examine the influence of self-efficacy on SL among graduates. This study will offer additional evidence highlighting the significant role of self-efficacy in fostering learners' SL, regardless of whether they have already obtained a bachelor's degree and possess work experience.

Teaching practices

Teaching practices refer to pedagogical actions taken by teachers inside or outside a classroom and shaped by school and classroom environments when planning, delivering lessons, managing classrooms, and interacting with students (Goe, 2007). Previous research has not indicated a direct impact of teaching practices on SL. Instead, it appears to influence factors such as academic achievement (Frome et al., 2005; Borman & Kimball, 2005), learning attitude (Che-ha, 2020), achievement motivation (Ostinelli, 2016), classroom size, and other related aspects (Burns & Ludlow, 2005). Even among individuals who have graduated with a bachelor's degree and possess work experience, teaching practices play a crucial role in facilitating learners' acquisition of practical knowledge and understanding. Adopting concrete teaching methods, such as incorporating real-life statistical examples and utilizing statistical package program materials, while offering ample opportunities for practice, analysis, and interpretation of results in diverse scenarios, can significantly impact their SL. Hence, it is imperative to explore whether teaching practices influence SL within this group of graduates. This research will provide an additional means to examine the significance of the teaching behavior factor in making learners SL and whether it also influences their learning attitude and achievement motivation, as demonstrated in past research.

Based on relevant theories and research, this study's conceptual framework and its independent and dependent variables are as follows (Figure 1):

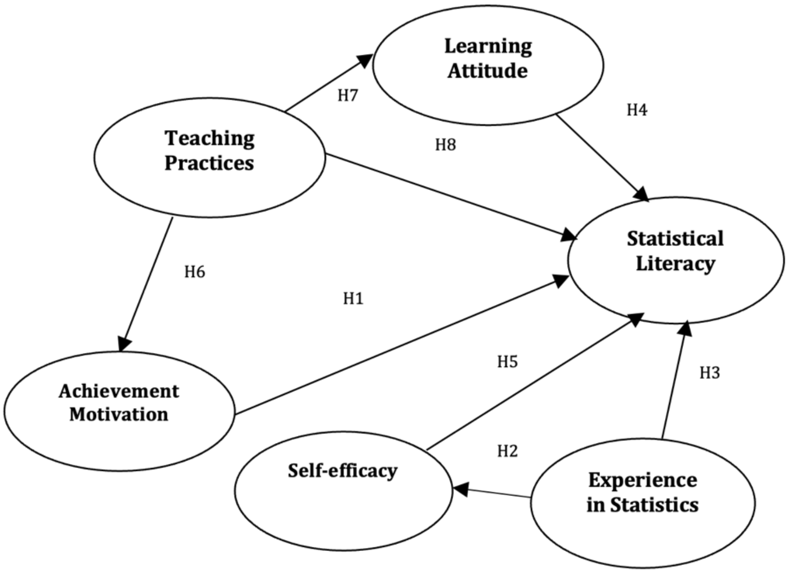

Figure 1: Conceptual research framework

Hypothesis development

H1: Achievement motivation has a positive influence on SL

H2: Experience in statistics has a positive influence on self-efficacy

H3: Experience in statistics has a positive influence on SL

H4: Learning attitude has a positive influence on SL

H5: Self-efficacy has a positive influence on SL

H6: Teaching practices has a positive influence on achievement motivation

H7: Teaching practices has a positive influence on learning attitude

H8: Teaching practices has a positive influence on SL

METHODOLOGY

Population and sample

The population of this study comprises an unknown quantity of master and doctoral graduates in Thailand. The sample was drawn from 10 educational institutes and included graduates from both master's and doctorate programs. Convenient sampling was used, and the participants were selected through coordination with alumni representatives from each educational institution. The test and questionnaire were designed to take approximately 10-15 minutes, and the research tool was accessible via the URL: https://forms.gle/dvp39sRrom8WAidb9. The sample size was calculated based on Cohen's (1992) method with five latent variables at the .05 significance level with 80% power of the test and approximately 25% acceptable R-squared values. Consequently, 70 participants were deemed to be the ideal number. However, 90 complete returned responses were obtained. Moreover, this study was ethically approved by Prince of Songkla University, Pattani Campus, with the approval code of psu.pn.2-015/64, to conduct human research.

Instruments

The research instruments were created in line with Windish et al. (2007) to assess statistical knowledge. They consist of 16 items, structured as four multiple-choice questions, along with nine items in a questionnaire aimed at evaluating opinions and confidence in using statistics. Additionally, the tools follow the approach by Che-ha (2020) for assessing SL based on Gal (2002), comprising 16 items in the form of complex true/false questions, multiple-choice questions, and fill-in-the-blank questions. Furthermore, there are 22 items in a questionnaire designed to assess opinions and the level of practice in learning statistics. The specific details of these research tools are as follows:

1. The SL test contains nine response items in the form of complex true/false questions, fill-in-the-blank questions, and questions for short-essay answers. The content of these items encompasses both descriptive and inferential statistics concepts, in line with the guidelines for teaching statistics in Thailand. More specifically, these response items were categorized into five dimensions based on Gal (2002)'s knowledge element, these dimensions are widely utilized and cover a diverse range of age groups. (e.g. Che-ha, 2020; Lukman & Wahyudin, 2020; Rahmawati et al., 2022) including 1) a response item on literacy skills, the basic knowledge required to understand, interpret, and evaluate data to produce statistical information. The respondent were requested to assess sentences and texts based on the provided image, comparing percentages or instances of object quantities; 2) two response items on mathematical knowledge, the knowledge and ability to use basic mathematics to interpret statistical data. The respondent were requested to assess proportions and central tendency in data; 3) two response items on statistical knowledge, the ability to use basic knowledge of statistics to understand and interpret statistical texts. The participants were asked to extract simple information from graphical data and review numbers in an ANOVA table; 4) two response items on context knowledge, the ability for placing statistical texts within real-life scenarios, enabling the interpretation and understanding of their importance. The participants were tasked with conducting hypothesis testing using t-tests in experimental research and interpreting conclusions through multiple regression in survey research; and 5) two response items on critical questions, the ability to evaluate statistical texts and verify the reasonableness of the research results. The participants were tasked to critically consider additional issues to be presented in the ANOVA or interpreted as the conclusions of the ANOVA with interaction. These response items were worth four scores each, totaling 20.
2. The 5-point Likert scale estimator questionnaire contains 30 response items, in five factors (six each), including achievement motivation, experience in statistics, learning attitudes, self-efficacy, and teaching practices. The five rating scores either refer to operational

frequencies or agreement levels, including always/strongly agree, often/agree, sometimes/unsure, rarely/disagree, and never/strongly disagree.

Data analysis

1. A thorough analysis was conducted on the test to identify any SL deficiencies. This analysis involved content analysis with rubric scoring for each test item, and the accuracy of scoring was independently verified by two test examiners. Furthermore, descriptive statistics, including percentage, minimum value, maximum value, mean, standard deviation, and median, were utilized to aid in the analysis process. Furthermore, the SL scores were analyzed based on specific criteria for interpretation. These criteria included idiosyncratic (0–1.00), transitional (1.01–2.00), quantitative (2.01–3.00), and analytical (3.01–4.00) categories. These divisions were established using quartile values and were influenced by the work of Saidi and Siew (2022) in order to assess the level of SL among graduates.
2. Additionally, the study examined variations in SL scores between master and doctoral graduates in research and statistics, as well as those in other fields of research and statistics using the Wilcoxon test. The aim was to compare the level of SL among graduates in each respective field of study.
3. Moreover, the questionnaire data underwent analysis utilizing descriptive statistics, including mean, and standard deviations. The interpretation of the results followed specific criteria: scores falling within the range of 4.21-5.00 indicated "always/strongly agree," 3.41-4.20 denoted "often/agree," 2.61-3.40 represented "sometimes/unsure," 1.81-2.60 meant "rarely/disagree," and 1.00-1.80 reflected "never/strongly disagree," as guided by the principles outlined by Pimentel (2010).

The hypothesis was assessed utilizing the Partial Least Squares-Structural Equation Model (PLS-SEM) along with bootstrapping, carried out using the SmartPLS 3.0 software package. This nonparametric approach employs resampling techniques, often applied for research objectives involving exploratory factor analysis, ensuring convergence, especially in cases involving small sample sizes or when a formative model is employed (Ringle et al., 2012). It's worth noting that PLS-SEM differs from the conventional Structural Equation Model (SEM), which is a parametric method commonly utilized for confirmatory factor analysis, particularly when dealing with larger sample sizes. Initially, the model is executed concurrently, and subsequently, the effectiveness of each measurement model is evaluated. Further updates or adjustments are then considered based on the evaluation results.

In this study, the dependent variables are structured as part of a formative model. This means that the formative indicators are derived from all observed variables, collectively contributing to their respective latent variables. In other words, the formative model was required or the latent variables were composed of the measures. In terms of independent variables, the reflective model contained some or all reflective indicators of the observable variables to form a latent. In other words, measures were representative of the variables, which are called reflective indicators (Garson, 2016). However, the assumption of PLS-SEM is assessed through various indicators, including Cronbach's alpha coefficients, convergent validity, discriminant validity, factor loading, effect size, coefficient of determination, and goodness of fit (GOF).

To ensure the quality of the research tools, five experts holding doctoral degrees and possessing at least 10 years of teaching experience in statistics were engaged. Each test item attained a content validity index (I-CVI) score of 1, highlighting their exceptional content validity. The questionnaire items likewise obtained an I-CVI score of 1, successfully navigating a pilot phase involving 20 non-participant respondents. The test displayed an alpha Cronbach coefficient of .78, while the questionnaires exhibited an overall coefficient of .96, with individual factor coefficients at .92, .88, .90, .84, and .95.

RESULTS

The participants comprised 27 males (30.00%) and 63 females (70.00%). Furthermore, 28 of them graduated with a master's degree in research and statistics (31.11%), 32 (35.56%) with a master's in other specialization, 8 (8.89%) with a doctoral degree in research and statistics, 22 (24.44%) with a doctoral degree in other fields, 29 (32.22%) with graduation within the past three years, 39 (43.33%) with graduation within 3-5 years, and 22 (24.44%) with graduation longer than five years. Moreover, 12 (13.33%) regularly, 40 (44.44%) sometimes, 19 (21.11%) rarely, and 19 (21.11%) never utilized statistics. The research results are as follows:

Statistical literacy deficiencies among master and doctoral graduates in Thailand

First, the response item on literacy skills was a complex true/false question worth four points with four sub-items. In this item, the respondents were asked to review sentences and texts from the picture given and compared percentages or instance of objects quantities. Results indicated that the participants had a mean score of 3.37 in literacy skills at a median of 4, indicating that they had the fundamental knowledge needed to understand, interpret, and assess data to extract statistical information at the analytic level.

Second, in terms of mathematical knowledge, two short-answer items with four total points required the participants to go over proportions and central tendency in data. Consequently, they produced a mean of 2.31 and a median of 2, indicating their knowledge and ability to use basic mathematics to interpret statistical data were at the quantitative level. More specifically, 67 (74.44%) provided the correct answers on the item presenting incorrect proportions, whereas 23 (25.66%) answered incorrectly. Furthermore, 28 (31.12%) of them provided a correct answer to the question on central tendency asking why the researcher presented median in combination with means. These participants provided reasons that the difference between the minimum and maximum values was large and the data tends not to create a normal curve. Furthermore, 22 (24.44%) partially provided a correct answer with reasons for the decisions and clarification. However, 40 (44.44%) answered incorrectly and did not provide a tangible reason. Specifically, they only indicated the interpretation of the median values, the sample group was too small, or there were different samples in each group.

Third, in terms of statistical knowledge, two short-answer items were used, comprising four sub-items and producing a total score of four points. The participants were asked to extract simple information from graphical data and review numbers in an ANOVA table. As a result, they produced a mean of 2.06 and a median of 2, suggesting that they had the ability to use basic knowledge of statistics to understand and interpret the statistical message at the quantitative level. More specifically, 81 of them (90%) were able to view graphs and provided correct answers to the question related to quantity and percentage, i.e., "How many times a week do most students spend time doing the activity and overall, which year of students spend more time on Facebook?" However, to a more difficult question such as "In this study, the participants include 104 electronic engineering students. How many students in total spend between 1-3 hours per day on Facebook?," only 44 (48.89%) answered it correctly. Furthermore, after reviewing values on the ANOVA table. Only 21 (23.33%) respondents answered correctly on the number of samples in the experiment, while 34 (37.78%) were wrong in the number of samples on the table as they disregarded n-1, 30 (33.33%) were correct on the number of treatments based on the df value, and 27 (30.00%) provided an incorrect answer to the number of treatments by disregarding n+1.

On the context knowledge element, two short-answer items were used, comprising three sub-items and producing a total score of four points. According to the t-test and multiple regression, the participants had a mean of 1.28 and a median of 1, meaning that they had the ability to put statistical texts in the right context for interpretation at the transitional level. In addition, only 22 (24.44%) were able to revise the text to draw a statistically correct conclusion from the question "Is it correct to interpret that the two sample group were not different with no statistical significance at the .05 level? if it is incorrect, how would you recommend this researcher?" Furthermore, only 6 out of 22 were able to provide a correct revision by stating that "The two sample groups were different with no statistical significance at the .05 level," which is a statistically correct summary sentence. On the contrary, the remaining 16 out of 22 provided roughly stated that "the two sample groups were different with statistical significance at the .05 level." Finally, 38 (42.22%) provided incorrect answers, and most of them perceived that the results were not different and neglected to indicate a degree of statistical significance. Furthermore, 30 (33.33%) were partially correct because they could indicate that the statement was incorrect but failed to correct it or only suggested that the t or p values should be reviewed. In conclusion, results from the regression analysis revealed the following insights to the question of "Which factor is most influential to decisions on purchasing a unit in Plum Condominium?" As a result, 11 respondents (12.22%) were correct in choosing the product factor. However, the majority, 50 (55.56%), chose reputation and image based on the b value, but they did not consider the beta value. The next question was "How much percentage can the above four marketing factors explain the participants' decisions on purchasing the condominium units?" More specifically, only 12 (13.33%) provided the most statistically correct answer, which was 65.3%, by referring to R-squared adjusted. In contrast, 35 (38.89%) chose 72.4% as their answer according to R-squared. However, 43 (47.78%) were incorrect for answering 38.89%.

In terms of the critical questions element, two short-answer items were used, totaling four points. In this element, the participants were tasked to critically consider additional issues to be presented in the ANOVA or interpreted as the conclusions of the ANOVA with interaction. Consequently, the participants yielded a mean of 0.89 and a median of 0, indicating that they had the ability to evaluate statistical texts and verify the reasonableness of the presentation at the idiosyncratic level. More specifically, the participants were able to choose additional issues to be presented on the ANOVA table. However, 26 respondents (28.89%) provided a correct answer. Furthermore, 18 (20%) suggested a comparison of life quality based on education levels, with details such as sex, age, status, and experience, which were irrelevant to the question, and 17 (18.89%) did not provide any answer. In terms of textual interpretations, a question was used and it stated that "The results showed no interaction between creativity and reading experience. How are the creativity and reading experience of this student group related to their ability to write academic articles?" Simply put, the ideal answer to this question should be their ability to write an academic article could depend on one or more factors, including creativity or reading experience. As a result, only 16 (17.78%) were correct. Furthermore, 28 (31.11%) suggested that a high degree of creativity and reading experience can translate to more effective academic writing capability. Finally, 10 (11.11%) indicated that they were not related and shared no effect.

The descriptive statistics and the overall results revealed that the participants had their SL scores lower than 50% within the transitional level (M=9.91, SD=3.38, Med=9.50/20) as described in Table 1.

Table 1: SL scores by elements (a full score of four points each with 20 total points)

Statistical Literacy	Min	Max	Mean	SD	Med	Result
Literacy Skills	0	4.00	3.41	0.87	4.00	Analytic
Mathematical Knowledge	0	4.00	2.31	1.33	2.00	Quantitative
Statistical Knowledge	0	4.00	2.12	1.14	2.00	Quantitative
Context Knowledge	0	4.00	1.28	1.11	1.00	Transitional
Critical Questions	0	4.00	0.92	1.27	0	Idiosyncratic
Total	1	18.50	9.91	3.38	9.50	Transitional

Statistical literacy scores across different educational levels in the fields of research and statistics and other disciplines

Based on the Kolmogorov–Smirnov test, the scores of literacy skills, mathematical knowledge, statistical knowledge, context knowledge, and critical questions were .339, .187, .148, .197, and .367, respectively with Sig.=.000 suggesting that this distribution of data was not normal. Therefore, the Wilcoxon test was alternatively used since it is a nonparametric test.

The contrastive analysis of the dimensions related to education and fields indicated that the doctoral graduates in Research and Statistics had a higher mean than master graduates in Research and Statistics with no statistical significance (doctoral graduates in Research and Statistics: M=12.69, Med=13.25; master graduates in Research and Statistics: M=10.82 Med=10.25, Z=-1.335, Asymp Sig.=0.182). In the same vein, doctoral graduates in other fields had a higher mean than master graduates in the same field with no statistical significance (doctoral graduates in other fields: M=9.73, Med=9; master graduates in the same field: M=8.89, Med=8.75, Z=-0.697, Asymp. Sig.=0.486). Moreover, the doctoral graduates in Research and Statistics had a significantly higher mean in statistical and context knowledge than the master graduates in the same fields at the Z values of -2.859 and -1.777, respectively. A similar scenario can also apply to graduates in other fields but without statistical significance, meaning that doctoral graduates had a higher mean than master graduates in the same field without statistical significance as described in Table 2.

Table 2: SL scores by education levels in Research and Statistics and other fields

Statistical Literacy		n	Min	Max	Mean	SD	Med	Z	Asymp. Sig.
Literacy Skills	Master in Research and Statistics	28	2	4	3.46	0.69	4.00	-1.365	0.172
	PhD in Research and Statistics	8	2	4	3.00	0.93	3.00		
	Master in other fields	32	0	4	3.50	1.02	4.00	-1.072	0.284
	PhD in other fields	22	1	4	3.36	0.85	4.00		
Mathematical Knowledge	Master in Research and Statistics	28	0	4	2.64	1.25	2.50	-0.322	0.747
	PhD in Research and Statistics	8	0	4	2.75	1.49	3.00		
	Master in other fields	32	0	4	1.89	1.36	2.00	-1.246	0.213
	PhD in other fields	22	0	4	2.34	1.25	2.25		
Statistical Knowledge	Master in Research and Statistics	28	0	4	2.02	1.08	2.00	-2.859	0.004***
	PhD in Research and Statistics	8	2	4	3.31	0.79	3.50		
	Master in other fields	32	0	4	1.98	1.10	2.00	-0.072	0.942
	PhD in other fields	22	0	4	2.02	1.19	2.00		
Context Knowledge	Master in Research and Statistics	28	0	4	1.48	1.07	1.50	-1.777	0.076*
	PhD in Research and Statistics	8	0.5	4	2.38	1.38	2.75		
	Master in other fields	32	0	4	0.94	0.97	1.00	-0.611	0.541
	PhD in other fields	22	0	3.5	1.09	0.99	1.00		
Critical Questions	Master in Research and Statistics	28	0	4	1.21	1.47	0	-0.336	0.736
	PhD in Research and Statistics	8	0	2	1.25	1.04	2		
	Master in other fields	32	0	4	0.59	1.04	0	-0.952	0.341
	PhD in other fields	22	0	4	0.91	1.31	0		
Total	Master in Research and Statistics	28	4.5	17	10.82	3.24	10.25	-1.335	0.182
	PhD in Research and Statistics	8	8	18	12.69	3.08	13.25		
	Master in other fields	32	1	14.5	8.89	3.21	8.75	-0.697	0.486
	PhD in other fields	22	4	18.5	9.73	3.26	9.00		

* $p < 0.10$ *** $p < 0.01$

The causal relationship in statistical literacy among master and doctoral graduates in Thailand

After analyzing the response items within the five factors, results revealed that achievement motivation's MOT2: “Statistical knowledge helps me progress with my education or profession” obtained the highest mean (M=4.11, SD=.99), followed by MOT4: “Statistical knowledge allows me to manage large amounts of numerical data promptly” (M=4.10, SD=1.01)In terms of experience in statistics, EXP4: “I used to present numerical data in a table, diagrams, and graphs” had the highest mean (M=4.04, SD=.91), followed EXP5: “I used to analyze numerical data with software or calculate them with simple formulas” (M=3.84, SD=1.12). For learning attitudes, ATT6: Statistics is a discipline that equips individuals with essential skills to explain large numbers of numerical data in a simple way that is easy to understand” gained the highest mean score (M=4.59, SD=.63), followed by ATT5: “Statistics is a discipline that allows individuals to analyze data with accuracy” (M=4.53, SD=.71) as highlighted in Table 3.

Table 3: Means and standard deviations of the response items on achievement motivation, experience in statistics, learning attitudes, self-efficacy and teaching practices

Item	Statement	Mean	SD	Interpretation
MOT1	I am committed to using statistical knowledge to maximize my academic achievement.	4.01	1.02	Agree
MOT2	Statistical knowledge helps me progress with my education or profession.	4.11	.99	Agree
MOT3	Statistical knowledge offers me the opportunity to regularly improve my skills.	3.98	1.12	Agree
MOT4	Statistical knowledge allows me to manage large amounts of numerical data promptly.	4.10	1.01	Agree
MOT5	I feel enthusiastic when seeing statistical data, and they often challenge me to learn more.	3.98	1.03	Agree
MOT6	I see lengthy and complex statistical data as a challenge to overcome to succeed educationally or professionally.	3.97	1.12	Agree
EXP1	I have seen or studied statistical data both in print and electronic media.	3.37	1.22	Sometimes
EXP2	I can easily understand statistical data.	3.06	1.05	Sometimes
EXP3	I incorporate statistical data from media for making decisions and planning.	3.44	1.19	Often
EXP4	I used to present numerical data in a table, diagrams, and graphs.	4.04	.91	Often
EXP5	I used to analyze numerical data with software or calculate them with simple formulas.	3.84	1.12	Often
EXP6	I can interpret analyzed numerical data to support or refute assumptions on a subject matter.	3.38	1.09	Sometimes
ATT1	Statistics is a discipline that helps individuals succeed in planning and making decisions.	4.27	.89	Strongly agree
ATT2	Statistics is a discipline that equips individuals with reasoning skills driven by data and knowledge.	4.44	.77	Strongly agree
ATT3	Statistics is a discipline that encourages individuals to think, take action, and make decisions.	4.26	.87	Strongly agree
ATT4	Statistics is a discipline that can be applied to other disciplines for developing new knowledge.	4.52	.74	Strongly agree
ATT5	Statistics is a discipline that allows individuals to analyze data with accuracy.	4.53	.71	Strongly agree
ATT6	Statistics is a discipline that equips individuals with essential skills to explain large numbers of numerical data in a simple way that is easy to understand.	4.59	.63	Strongly agree
EFF1	Even though I was assigned to work with large and complex numerical data, I believe I have the ability to accomplish the task.	4.07	1.02	Agree

Item	Statement	Mean	SD	Interpretation
EFF2	I am confident that I can effectively use surveys and polls to improve my organization.	4.07	.96	Agree
EFF3	I believe that I can effectively use and explain to others ways to operate statistical software.	3.63	1.11	Agree
EFF4	I am confident that I can explain the meanings of data and numbers corresponding to relevant realities and contexts.	3.82	.96	Agree
EFF5	When an assignment contains numerical data, I would take it straight away.	3.61	1.28	Agree
EFF6	I am confident that statistics can be applied to other disciplines for organizational development.	4.07	.93	Agree
PRAC1	My teachers had given me advice, asked questions, or made comments on learning statistics.	3.99	1.01	Agree
PRAC2	My teacher's choices of content for statistical lessons matched learner interests and aptitudes.	3.84	1.06	Agree
PRAC3	My teacher uses the teaching materials relevant to the content of my statistics courses, and they help me understand the content more effectively.	3.84	1.08	Agree
PRAC4	My teacher uses statistical content that is relevant to current situations, and it helps me visualize and understand the content more easily.	3.83	1.17	Agree
PRAC5	My teacher encourages learners to take initiative and offer criticism after learning about statistical content.	3.87	1.09	Agree
PRAC6	My teacher's teaching methods gave me confidence and a positive attitude toward learning statistics.	3.87	1.07	Agree

In terms of self-efficacy, EFF6, "I am confident that statistics can be applied to other disciplines for organizational development," produced the highest mean score (M=4.07, SD=.93), followed by EFF2, "I am confident that I can effectively use surveys and polls to improve my organization," (M=4.07, SD=.96). In terms of teaching practices, PRAC1, "My teachers had given me advice, asked questions, or made comments on learning statistics," yielded the highest mean (M=3.99 SD=1.01), followed by PRAC6, "My teacher's teaching methods gave me confidence and a positive attitude toward learning statistics," (M=3.87 SD=1.07) as illustrated in Table 3.

The internal consistency reliability of the items based on the independent variables within the reflective model produced Cronbach's alpha coefficients in the range of .896-.970, which were acceptable since they were greater than .80 according to Hair et al. (2011). This means that the response items of each factor were internally consistent and were adequate to jointly explain that factor. Furthermore, since the average variance extracted values (AVE) were in the range of .708-.870, they were acceptable for exceeding .50 according to Ramayah et al. (2016). In terms of discriminant validity, according to the Fornell-Larcker criteria, the values within the diagonal line were in the range of .841-.933, which were greater than those outside the diagonal line of the matrix that was from 166 to .804. Furthermore, the Heterotrait-Monotrait (HTMT) values were in the range of .531-.854, which were acceptable since they were lower than .90 according to Ramayah et al. (2016). The data indicated that the response items of the measurement model could adequately measure specific factors within its model. In terms of multicollinearity, PLS-SEM analysis suggested that the observed variables in the reflective and formative models produced VIF values in the range of 1.000-3.787, which were acceptable since they were lower than 5 according to Hair et al. (2014). The figures showed no multicollinearity was identified across the five factors. The measurement model revealed that "mathematical knowledge" yielded the highest main loading (.833), followed by "critical questions" (.327), "literacy skills" (.267), and "statistical knowledge" (-.053), respectively. Furthermore, the response items from the experience in statistics factor produced factor loadings from .797-.901, whereas achievement motivation had the factor loadings from .808-.923, learning attitudes from .794-.885, self-efficacy from .816-.905, and teaching practices from .905-.955.

Evidently, factor loadings that are greater than .700 were considered acceptable according to Ramayah et al. (2016). Consequently, EXP1, "I have seen or studied statistical data both in print and electronic media," was eliminated for producing a factor loading that is lower than .700. However, the SL component was not removed from its model regardless of its factor loading because the model was formative (Figure 2).

The PLS-SEM results were found to support the five research hypotheses at the R^2 of .283, which is close to .33, and indicated that the model was moderately suitable based on Chin (1998). Hence, the five factors could explain SL at 28.3%. Furthermore, since GoF was .589, which was close to .360, the model was considered to be highly suitable according to Wetzels et al. (2009). In general, the results confirmed that four of the hypotheses were valid (Table 4). Details are further discussed below.

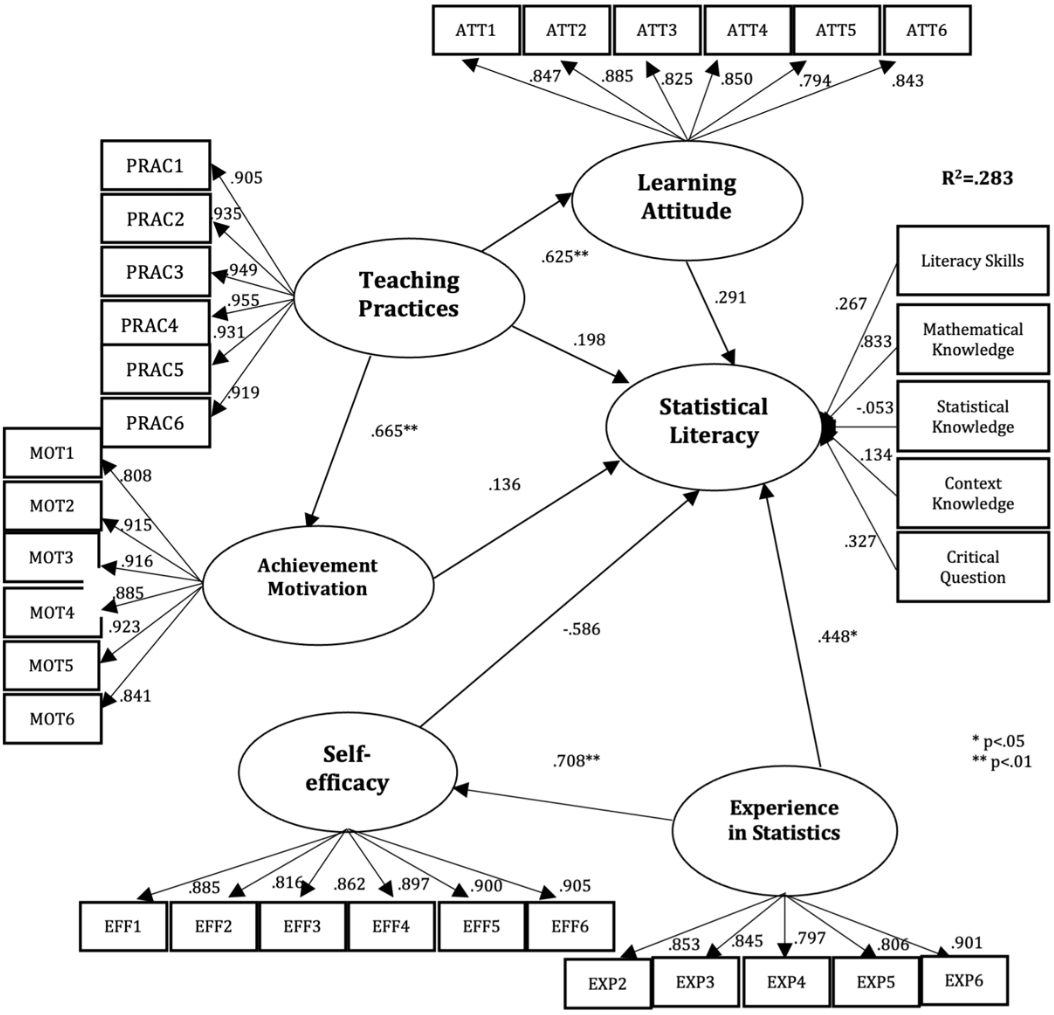

Figure 2: PLS-Path analysis of statistical literacy

H2: Experience in statistics has a statistically significant positive influence on self-efficacy with t = 12.024 p-value = .000

H3: Experience in statistics has a statistically significant positive influence on SL with t = 1.974 p-value = .048

H6: Teaching practices has a statistically significant positive influence on achievement motivation with t = 9.080 p-value = .000

H7: Teaching practices has a statistically significant positive influence on learning attitude with t = 10.994 p-value = .000

Table 4: Significance of direct effects- Path coefficient (n=90)

H	Path	Beta value	SE	t-value	p-value	Result
1	Achievement Motivation -> SL	.136	.317	.430	.667	Not Supported
2	Experience in Statistics -> Self-efficacy	.708	.059	12.024	.000**	Supported
3	Experience in Statistics -> SL	.448	.227	1.974	.048*	Supported
4	Learning Attitude -> SL	.291	.271	1.074	.283	Not Supported
5	Self-efficacy -> SL	-.586	.320	1.833	.067	Not Supported
6	Teaching Practices -> Achievement Motivation	.665	.073	9.080	.000**	Supported
7	Teaching Practices -> Learning Attitude	.625	.057	10.994	.000**	Supported
8	Teaching Practices -> SL	.198	.262	.755	.450	Not Supported

*p<.05 **p<.01, SE: Standard Error

DISCUSSION

Statistical literacy deficiencies among master and doctoral graduates in Thailand

The results of the SL analysis suggested that the master and doctoral graduates in Thailand had overall SL scores lower than 50%, falling into the transitional bracket. More specifically, literacy skills obtained the highest middle value (analytical), followed by mathematical knowledge and statistical knowledge (quantitative), context knowledge (transitional), and critical questions with the lowest middle value (idiosyncratic). Consistently, Yotongyos (2013) also published that undergraduate students in Thailand had the highest scores in literacy and statistical knowledge, followed by mathematical knowledge, context knowledge, and critical skills, respectively. Similarly, Che-ha (2020) reviewed SL among Secondary 3 students in Thailand and stated that their literacy skills had the highest mean score, followed by mathematical knowledge, statistical knowledge, and context knowledge, respectively. Similarly, Cimpoeru and Roman (2018) revealed that tertiary students in Romania had the highest mean score in literacy skills, followed by statistical knowledge and mathematical knowledge, respectively. The outcomes shown above might have been impacted by the duration since graduation and the frequency of statistics utilization. It's worth noting that 43.33% of participants had graduated within the 3-5 year range, while 24.44% had completed their studies more than five years ago. Additionally, 42.22% of respondents reportedly used statistics occasionally, rarely, or never. This variance could stem from the varying difficulty levels within the SL components, with literacy skills being rated as easy and critical questions as difficult. However, the most concerning aspect emerges from the SL of graduate students, whose overall scores fall below half of the total attainable score. This highlights potential shortcomings in instructional management, leading to an inability to address test questions, possibly due to fading subject knowledge or answering with uncertainty.

The participants had relatively high literacy skills, with scores beyond 80%. However, their mathematical and statistical knowledge was only slightly higher than 50%. As many as 25.66% provided incorrect answers to the question about proportions, whereas 68.88% were partially correct and incorrect when answering the questions on central tendency. Furthermore, 51.11% were incorrect on the response items on the conversion of proportions. In fact, these questions based on the three elements above are the content that the participants had already studied since secondary school. Moreover, questions about literacy skills were commonly available in print and social media. Hence, it is safe to assume that the participants were already familiar with this type of content. Consequently, they did not seem to find it difficult to draw a suitable conclusion and earned relatively high scores. Contrarily, the participants earned relatively low scores in the mathematical knowledge element although this element shares the same difficulty level with the previous counterpart. A possible explanation would be that the participants did not fully understand how the proportions are calculated. In fact, more than half could not provide an explanation, elaborate with an accurate interpretation of the types of central tendency and their respective utilization, or convert proportions to quantities as required.

Based on the statistical-knowledge question related to ANOVA, content commonly taught at the undergraduate and graduate levels, it was found that as high as 70% of the participants answered incorrectly, suggesting that they could use basic statistical knowledge to understand a situation but could not interpret statistical texts. The notion is in line with Windish et al. (2007), which asserted that only 50.2% and 47.3% of fellows and residents in Germany could provide a correct interpretation of standard deviations and ANOVA, respectively. Congruently, the participants also suggested that "teachers should teach statistical content using a technique that is easy for them to understand, enjoy numbers, and be able to apply with work and organizations in the future." Furthermore, they "wish to learn statistics through visualization and practical application so that they could see the importance of statistics when applied to real-life situations." They also suggested that "statistics should be taught with case studies and daily applications." As Garfield (1995) put it, teaching techniques are a contributing factor. If mathematical and mechanical knowledge became the emphases in statistical learning, students might not have enough opportunities to improve problem-solving skills.

The participants scored below 50% in both contextual knowledge and critical questions, it means that they could not put statistical texts in the right context for interpretation and understanding their meanings. Evidently, approximately 70% either provided incorrect or partially correct answers. A possible explanation is that context-knowledge questions are of bachelor's and master's difficulties. Understandably, hypothesis testing with t-tests and multiple regression analysis is moderately difficult to understand, interpret, summarize, and suggest in a theoretically correct manner. Furthermore, students might not, if ever, use it very often from the first to the final years of education. Consequently, the participants earned a low score in this aspect. This evidence further reflects that the participants could not effectively evaluate statistical texts and verify the reasonableness of the presentation. More specifically, approximately 70-80% of them were incorrect or partially incorrect when answering critical questions, which are of bachelor's and master's difficulties. Since their content is related to ANOVA and ANOVA with interaction, the participants might find it difficult to understand, interpret, summarize, validate, and make a theoretically sound suggestion.

This notion corresponds to Windish et al. (2007) on the German fellows and residents as 11.9%, 37.4%, and 56.7% of them had correct answers on statistical significance, multiple regression, and other specific issues, respectively. On the bright side, it is possible to improve these results with regular utilization and training. According to Jenny et al. (2018), training does not have to be lengthy or overcomplicated since a short session was found to improve SL among German students in Medicine by 40%. Also, the participants suggested that "since Statistics is a difficult subject matter, modified inputs such as media and infographics are essential learning facilitation that makes statistics lessons more understandable and exciting." Another suggestion was that "There should be more teaching materials available for students so that they could grasp the statistical concepts more effectively. Authentic data would be ideal for practicing and analyzing to enhance statistical understanding." The aforementioned findings might necessitate educators to modify instructional approaches in order to enhance learners' retention of knowledge. Furthermore, it could signal the need for additional skill development through re-skilling and up-skilling initiatives, accompanied by training or coaching. This targeted effort aims to acquaint individuals with contextual and critical skills, ultimately resulting in an augmented level of SL.

Statistical literacy scores across different educational levels in the fields of research and statistics and other disciplines

When comparing dimensions related to educational levels in the domains of Research and Statistics against other fields, it is evident that Research and Statistics graduates achieved SL scores that exhibited a slight variation from graduates in different fields. Notably, among doctoral graduates in Research and Statistics, the mean SL score surpassed that of master's graduates within the same domain, displaying statistical significance, particularly in the areas of statistical knowledge and contextual understanding. The results are consistent with Windish et al. (2007), reporting that mean scores in a biostatistics test produced by residents and fellows were significantly different (41.4% vs 71.5%), even though 95% of them perceived that the test was relevant to their academic understanding of science. Moreover, Berndt et al. (2021) found that undergraduate and graduate students in Social Sciences in Germany had lower SL scores than those in Medicine and Economics and added that SL was not related to scientific reasoning and argumentation skills. However, in contrast to the findings of Onwuegbuzie (2001), which argued that doctoral students in the United States generally demonstrated higher critical thinking than master graduates at a significant level. Interestingly, the preceding outcomes displayed a marginal superiority among Research and Statistics graduates compared to their counterparts from other disciplines. Furthermore, to a more astonishing degree, individuals holding a PhD in research and statistics-focused areas did not achieve higher scores in critical skills in comparison to master's degree holders within the same field. This is noteworthy considering that PhD holders have had numerous opportunities to acquire substantial expertise in reading research. This observation raises the possibility that the teaching and learning approaches at both levels, encompassing various fields including research and others, in Thailand might not have discerned disparities in imparting experience related to research and data analysis skills. Further investigation into this matter is warranted for future studies.

The causal relationship in statistical literacy among master and doctoral graduates in Thailand

According to the measurement models, statistical knowledge received a negative value, reflecting the presence of the suppression effect resulting from some elements being correlated (Garson, 2016). Indeed, statistical knowledge is significantly correlated with mathematical knowledge and context knowledge. Hence, it can be implied that SL in this context should only comprise mathematical knowledge, critical questions, context knowledge, and literacy skills, which differ from the predetermined set of elements. Consequently, this newly refined set of elements should be studied further in conjunction with newly modified categories of questions for improved relevance. Alternatively, further studies might consider increasing the number of questions or participants. The hypothesis testing confirmed that four hypotheses were validated with the ability to explain the low variation of SL, with an R^2 of 28.4. However, the mean scores derived from the questions within the five factors implicated that the participants might have rated themselves with high scores. Looking deeper into each factor, it was found that only literacy skills obtained scores beyond 80%, whereas context knowledge and critical questions did not exceed 50%. This phenomenon implies that participants assigned similar self-assessment scores to themselves. Conversely, the SL scores displayed notable differences, underscoring the consequence of employing a test as the measuring instrument for the dependent variable. It's noteworthy that when utilizing questionnaires for self-assessment as the measurement of independent variables, a low R^2 value became apparent. This outcome resembles the conclusions drawn by Che-ha (2020), who reported an R^2 value of merely .10, despite a sample size of 350 individuals. Furthermore, since experience in statistics was found to be the only element with a direct influence on SL, the participants who had presented, analyzed, interpreted, and applied statistical data in decision-making and planning might achieve higher SL. The notion is congruent with Torteeka (2020), suggesting that experience in statistics was the most directly and positively influential factor shaping students' SL. Similarly, Che-ha (2020) reviewed SL among Secondary 3 students in Thailand and stated that their experience in statistics was significant to SL after achievement motivation. Zieffler et al. (2008) indicated that existing knowledge plays a crucial role in statistical teaching. Consistently, Dempster and McCorrey (2009) published results obtained from statistics assessment and discussed that they were more influenced by attitudes towards cognitive competence than experience in statistics.

Moreover, since experience in statistics also had a direct influence on self-efficacy, it means that the participants who had presented, analyzed, interpreted, and applied statistical data in decision-making and planning might also have high self-efficacy. On this note, it also means the participants felt confident that they could successfully work with data, explain or use statistical software, and apply statistics for organizational development. The results were similar to Carmichael et al. (2010), suggesting that age and self-efficacy were correlated with interest in SL among middle school students in Australia. In the same vein, McGrath et al. (2015) discovered that students in Canada demonstrated higher statistical self-efficacy after learning from diverse methods, including using orientation letters, discussing obstacles in statistics learning, and incorporating funny stories. The above results confirm that teaching statistics at the graduate level needs some learning facilitation and simplification such as associating with situations in everyday life and presenting information in tables, figures, charts, and graphs, which would provide graduates some sense of confidence in managing and analyzing data in the future. According to GAISE College Report ASA Revision Committee (2016), the Guidelines for Assessment and Instruction in Statistics Education provide recommendations on steps to transform statistics teaching, and they include 1) teaching statistical thinking, 2) highlighting knowledge of concepts instead of steps, 3) incorporating authentic data, 4) increasing active learning, 5) integrating technology in conceptual learning and data analysis, and 6) enhancing learning with evaluation. Nonetheless, it's important to recognize that self-efficacy can also exert a direct negative influence on SL. Another potential scenario is that participants may have overly inflated their self-efficacy ratings, while their actual SL performance turned out to be below expectations. Alternatively, certain participants might not have put forth their optimal effort during the SL test due to lacking motivation, or it's conceivable that the chosen sample group might not possess the necessary capability to complete the test effectively. Rectifying this issue is crucial to achieve a more precise interpretation of the findings. This has led to a collaborative effort with alumni representatives from each institution, aimed at ensuring the selected test samples meet relevant criteria. Furthermore, these representatives have validated the samples' competence in effectively completing the necessary assessments to their highest capacity. However, the results were not congruent with some studies in statistics and mathematics achievement such as Carmichael et al. (2010), Karakolidis et al. (2016), Kalaycioglu (2015), and Mundia and Metussin (2019).

Also, teaching practices had a direct impact on achievement motivation and learning attitudes. This phenomenon reflected that the participants had been exposed to the learning experience where their teachers included current situations, simplified teaching materials, and frequently encouraged classroom discussion. As a result, the participants demonstrated the ability to apply statistical knowledge for higher work-related advancement and achievement. Simply put, they possessed high achievement motivation. Furthermore, teaching practices also led to the participants' positive attitudes towards statistics as they reportedly believe that they can plan, decide, and take action with confidence based on statistical knowledge. This phenomenon echoes findings by Prasertsith (2014), who highlighted the impact of attitudes towards teachers on mathematics achievement among Science and Technology students. Similarly, Maneeprasert (2011) explored student-teacher relationships, revealing teaching environments' influence on achievement motivation in Engineering students. Blaza and Kraft (2017) affirmed upper-elementary teachers' significant influence on math self-efficacy and psychological well-being. Consequently, teaching practices, emotional support, and classroom atmospheres shape student attitudes and behaviors, as reflected in self-efficacy assessments. Hassad (2011) noted intention, teaching efficacy, and approach influenced teaching practices in introductory statistics courses for health and behavioral sciences. Umugiraneza (2018) outlined three strategies for enhancing statistics learning among African math teachers, including motivating learners and stimulating their eagerness to learn, developing ways to explain ideas while teaching, preparing lessons in advance, revisiting basic knowledge, encouraging practicing, and associating with authentic situations. Consequently, the above findings strongly validate the substantial impact of achievement motivation and learning attitudes across various dimensions in the educational landscape, extending even to the field of SL. This emphasizes the imperative for educators to intricately structure learning engagements, encompassing elements like curriculum design, media incorporation, resource materials, technology integration, and evaluation strategies. These endeavors are aimed at instilling robust motivation and nurturing a positive disposition among students towards the study of statistics and the proficient application of statistical knowledge in their future pursuits. By fostering an optimistic outlook on the subject, the desired educational outcomes, which educators strive to attain, should notably become more achievable and less formidable.

LIMITATIONS

1. Coordinating with alumni representatives from each institution for convenient sampling could yield a sample group with a predisposition to aid one another in tests and questionnaires. In forthcoming studies, opting for a probabilistic sample selection via a course instructor within an educational institution might lead to more clarified outcomes.
2. Due to the limited scope of the research sample, utilizing parametric techniques like SEM for data analysis was impractical. However, with the accumulation of a sufficiently extensive dataset, the use of the aforementioned statistical methods could enhance result clarity.
3. Research instruments combining tests and questionnaires pose challenges in data collection and might lead to unintended outcomes. Nonetheless, these challenges yield valuable insights and necessitate a more careful and rigorous data collection approach.

CONCLUSION

Although the participants' overall SL remained transitional, their literacy skills, mathematical knowledge, and statistical knowledge exceeded 50%, meaning that they possessed adequate fundamental knowledge for extensive development. Besides, the factors affecting SL also showed that experience in statistics was the only factor with a significant effect. Hence, it is evident that learners can improve their knowledge of statistics by practicing and enhancing skills based on existing experiences in presenting, interpreting, or analyzing data. With adequate knowledge, learners can plan and make decisions for their organizations more effectively with statistical data. The findings of this study were projected to benefit statistical teachers at any level who are planning to revise their teaching management, instructional approach, and pedagogical emphasis to encourage students to practice analytical thinking and progress through stages of SL with concrete progress. Further studies are suggested to explore deeper into statistical reasoning and thinking to identify their strengths for skill development and remaining SL deficiencies. Further studies are also suggested to tackle issues in teaching management and construct an assessment to measure the issues.

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