Factors Influencing Students’ Understanding of Basic Statistical Concepts

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Abstract

This study focused on modelling the influence of teaching practices, students’ attitudes towards statistics, learning practices and perceived ability on students’ understanding in basic statistical concepts using Structural Equation Modelling. A total of 416 students from four Malaysian public tertiary institutions made up the sample for this study. The results showed that students’ perceived ability in statistics has a strong influence on students’ understanding of basic statistical concepts (measured by performance) and students’ attitudes toward statistics. Teaching practices also significantly affect students’ learning practices. This study found that learning practices and teaching practices do not affect students’ attitudes toward statistics and do not lead to an increase in students’ understanding of basic statistical concepts as measured through their test performance.

Keywords: Learning of statistics, conceptual understanding, basic concepts of statistics, structural equation modelling, teaching and learning
INTRODUCTION

The conceptual understanding of statistical concepts is commonly recognized as one of the most significant elements of statistical knowledge. It refers to the ability to link understanding of statistical ideas and concepts into a network of interrelated propositions. Many researchers (e.g., Ben-Zvi & Garfield, 2004; Garfield, 1999; Rumsey, 2002; Watson, 2005) support the need to comprehend fundamental statistical concepts and terminology, including statistical symbols, as it is omnipresent and unavoidable in our day-to-day living. However, these researchers (as well as others) pointed out that understanding statistical concepts is not the same as understanding statistical mechanics; for example, plugging numbers into the correct formulae. In order to understand statistical concepts, the ability to read and use statistical tools – such as percentage, ratio, measures of spread, central tendency and variability, as well as tables, graphs and maps – is required. Crooks et al. (2019) added that conceptual understanding of statistics demands an understanding of the ‘why’ of statistics in addition to the ‘how’ of it. In addition to having procedural knowledge in solving a statistical problem, students must also have conceptual knowledge of statistics. “If students don’t understand the important concepts, there’s little value in knowing a set of procedures” (American Statistical Association, 2005, p.10).

Conceptual understanding has been characterized as knowledge that is rich in relationships, where discrete pieces of statistical knowledge, ideas and concepts are connected to construct a network of interrelated propositions (Broers, 2001; Hiebert & Lefevre, 1986). The construction of interrelated propositions can occur “between pieces of information already stored in the memory or between an existing piece of knowledge and one that is newly learned” (Hiebert & Lefevre, 1986, p. 3-4). Conceptual understanding, hence, is essential for the development of statistical reasoning and thinking. Without it, students would not be able to make connections and explain the relationships between the different statistical processes or discrete statistical knowledge (Ben-Zvi & Garfield, 2004, p.7).

Statistical concepts are the basis of learning statistics, and therefore, should be given due attention by every educational institution. Research on understanding basic concepts of statistics that has been conducted includes the following three areas: (1) reasoning about distributions and graphical representations of distributions (Bakker & Gravemeijer, 2004; Ben-Zvi, 2004; Hammerman & Rubin, 2004; Whitaker & Jacobbe, 2017); (2) understanding concepts related to statistical variation, such as measures of variability (DelMas & Liu, 2005; Mathews & Clark, 1997; Turegun & Reeder, 2011); and (3) sampling distributions (Braham & Ben-Zvi, 2017; delMas et al., 1999; Findley & Lyford, 2019; Saldanha & Thompson, 2001).

There are many factors that contribute to students’ understanding of basic statistical concepts and their success in statistics courses. Deep concerns have been raised by educators on the poor performance of students in these courses; thus, it is important to identify the causes of students’ poor understanding of the basics concepts to improve the teaching and learning of statistics. Since the classroom is a learning environment where interactions occur among students and instructors, students’ perceptions of their classroom learning environments and the factors associated with their perceptions may help us to find or devise some alternative ways to enhance student learning. Specifically, these factors include lecturers’ instructional practices,
the students’ own learning practices, and their attitudes towards statistics, as well as their perceived ability or self efficacy in learning statistics.

**Research Hypotheses and Proposed Model**

Hence, in this study, these variables were investigated whereby a structural model was developed to examine the causal relationships between them, given their significant roles in students’ successful learning of statistics. The hypotheses tested were as follows:

- **H1:** Students’ perceived ability will have a direct effect on students’ performance.
- **H2:** Students’ learning practices will have a direct effect on students’ performance.
- **H3:** Instructors’ teaching practices will have a direct effect on students’ performance.
- **H4:** Students’ attitudes toward statistics will have a direct effect on students’ performance.
- **H5:** Students’ perceived ability will have a direct effect on students’ attitudes toward statistics.
- **H6:** Students’ learning practices will have a direct effect on students’ attitudes toward statistics.
- **H7:** Instructors’ teaching practices will have direct effect on students’ attitudes toward statistics.
- **H8:** Instructors’ teaching practices will have direct effect on students’ learning practices.

Figure 1 displays the proposed model showing the relationships among the variables guided by the proposed hypotheses of the study.

**Figure 1**

*Structural model tested in the study*
LITERATURE REVIEW

Students’ Statistical Competencies and Conceptual Understanding

Statistical competencies, according to Rumsey (2002), underlie statistical reasoning and thinking. Without statistical competencies, statistical reasoning and thinking cannot be developed. Statistical competencies include data awareness, knowledge of certain basic statistical concepts and terminology, knowledge of the basics of collecting data and generating descriptive statistics, basic interpretation skills (i.e., the ability to describe what the results mean in the context of the problem) and basic communication skills (i.e., being able to explain the results to someone else) (Rumsey, 2002).

Huberty et al. (1993) argue that factors that appear to underlie statistical competence include: computational aptitude, propositional knowledge, and conceptual understanding. Computational aptitude is the ability to understand and use mathematical formulae while propositional knowledge and conceptual understanding relate respectively to the knowledge of statistical concepts and their interrelationships (Leppink, 2016). The process begins by developing a basic foundation of knowledge of statistical concepts and ideas (i.e., statistical competencies) where statistical competencies promote and develop skills in data awareness, production, understanding, interpretation, and communication.

Conceptual understanding, on the other hand, is knowing the procedural steps in solving a problem and at the same time, understanding why it works. Students who lack conceptual understanding may underperform due to their tendency to misconceive and misinterpret statistical concepts and statistical analysis. Hence, a major and an important goal of statistics education is to focus on developing a deep conceptual understanding of basic statistical concepts and statistical competencies in students. With good conceptual understanding and statistical competence, students would be able to make connections and explain the relationships between discrete statistical knowledge (Ben-Zvi & Garfield, 2004, p.7).

Conceptual understanding and statistical competencies are essential for the development of statistical literacy, reasoning and thinking (Mahmud et al., 2018). According to Ben-Zvi and Garfield (2004), statistical literacy includes “basic and important skills that may be used in understanding statistical information or research results” (p. 7). In addition, to be statistically literate in the proper meaning of the term, students must be able to extract, understand, and explain different representations of data (Gal, 2002; Garfield, 1999).

Statistical reasoning, on the other hand, refers to the way people reason with statistical ideas by means of interpreting and making inferences of the statistical results based on the sets of data, graphical representations and statistical summaries, such as distribution, centre, spread, association, uncertainty, randomness and sampling (Garfield, 2002). Ben-Zvi and Garfield (2004) define statistical reasoning as “the way people reason with statistical ideas and make sense of statistical information” (p. 7).

Statistical thinking involves an understanding of why and how statistical investigations are conducted and the ‘big ideas’ that underlie statistical investigations (Ben-Zvi & Garfield, 2004). This includes recognizing and understanding the entire investigative process, how
models are used to simulate random phenomena, how data are produced to estimate probabilities; how, when, and why existing inferential tools can be used, and utilizing the context of a problem to plan and evaluate investigations (delMas et al., 2007). One crucial aspect of statistical thinking is the ability to critique and evaluate statistical studies (Ben-Zvi & Garfield, 2004).

In summary, statistical literacy is the ability to understand and use the basic language and tools of statistics (i.e., identifying, describing, rephrasing, translating, interpreting, and reading). Statistical reasoning is the ability to choose, generate, and properly interpret appropriate descriptive and inferential methods and the ability to make inferences and justify conclusions (i.e., explaining the why and how of the process). Statistical thinking is the ability to understand why and how statistical investigations are conducted and knowing when and how to apply statistical knowledge and procedures (i.e., applying, critiquing, evaluating, and generalizing) (Mahmud et al., 2018).

Most research suggests that before any effort to educate students about statistical methods, instructors must first work on developing their statistical literacy, thinking, and reasoning. This must come first before teaching students appropriate statistical methods as basic knowledge in statistical literacy, reasoning, and thinking is needed for understanding published research (delMas et al., 2007), which is a critical skill that students need to have in order to conduct a good literature review.

In short, introductory statistics courses should focus on the basic foundation of statistical concepts and ideas where statistical literacy, reasoning and thinking are developed throughout the course. Students will then reinforce their understanding of statistical terms and concepts, and statistical literacy, reasoning and thinking skills along the process.

Factors Influencing Students’ Performance in Statistics Courses

Students’ performance in statistics courses at the undergraduate level has been of interest to researchers for many years. Many efforts have been made to investigate factors that affect a student's performance in a statistics course. These factors include instructors’ knowledge (Callingham et al., 2016), the teaching and learning environment (Semukono et al., 2013), attitude (Naccache, 2012; Rochelle & Dotterweich, 2007), anxiety (Hoegler & Nelson, 2018; Hedges, 2017; Abd Hamid & Sulaiman, 2014), perceived ability or self-efficacy (Hoegler & Nelson, 2018; Lane et al., 2004), learning practices (Ariffin et al., 2014), learning behaviour (Luc Bude et al., 2007), teaching practices (Gundlach et al., 2015; Wilson, 2013), use of technology in learning (Tchantchane et al., 2012), gender (Monroe et al., 2011) and age (Dutton & Dutton, 2005).

In previous studies, a number of models were developed to predict and measure students’ performance (Skaalvik et al., 2015; Badiee et al., 2014; Yurt & Sunbul, 2014; Emmioğlu, 2011; Onwuegbuzie, 2003). For example, Alyani and Nurañfi (2019) presented a model where gender, age and educational background were predictors of a student’s GPA. Brezavšček et al. (2020), using the same approach, examined the relationships among the factors influencing students’
mathematics achievement which included attitude towards mathematics and math anxiety, engagement in learning activities, and attitude towards the use of technology in learning mathematics. Garfield et al. (2002) suggested that the desired outcomes of introductory statistics courses should include not only statistical learning and understanding, but also the willingness of students to persist in their learning and application of skills, as well as positive attitudes and beliefs about statistics.

As students are part of the teaching and learning environment, their voices and perspectives are of great significance and need to be investigated in order to improve the process of teaching and learning statistics. It is also important to examine the relationship between statistics teaching and learning and the factors that influence students’ conceptual understanding of statistical concepts. While there are numerous factors that affect the performance of students in statistics, as evident in the existing literature, this research aims to explore student attitudes, perceived ability, learning practices and teaching practices which are considered important variables that contribute to students’ understanding of basic statistical concepts and key factors to succeed in statistics courses.

**Influence of students’ perceived ability on their performance and attitudes toward statistics**

Students’ perceived ability may have a profound influence on their learning outcomes and attitudes towards statistics. Perceived ability or self-efficacy as one of the concepts under the Social Learning Theory by Bandura (1997) has served as a basis to further understand an individual’s motivation to learn and their learning pursuits as it is one of the predictors of academic success. Self-efficacy is defined as self-beliefs or self-judgement that students perceive about their ability to successfully complete a specific task (Bandura, 1997). It is considered as one of the fundamental factors in learning basic statistical concepts in terms of attitudes, where it determines the feeling, thinking, motivation and behaviour of the student.

Finney and Schraw (2003) defined statistics self-efficacy as the “confidence in one’s abilities to solve specific tasks related to statistics” (p. 164). They developed measures to assess self-efficacy in statistics that comprise students’ current self-efficacy in statistics (CSSE) and self-efficacy to learn statistics (SELS). They investigated whether self-efficacy affected students’ performance in a statistics course and found that students’ statistical achievement and their self-efficacy were positively related. Other researchers have also found a significant relationship between self-efficacy and academic achievement (Awang-Hashim et al., 2002; Finney & Schraw, 2003; Goulão, 2014; Lampert, 2007; Lane et al., 2004; Onyeizugbo, 2010).

It is unfortunate that many students perceive statistics as a difficult subject even before studying statistics (Baharun & Porter, 2009). Perceived level of difficulty or perceived ability can affect students’ attitudes toward learning statistics (Estrada et al., 2005) and the primary concern is that a perception of difficulty will lead to avoidance or lack of learning engagement, if given a choice (Fitzmaurice et al., 2014).
Influence of students’ learning practices on their performance and attitudes toward statistics

Learning practices also play a role in optimising academic performance (Diseth et al., 2010; Kizilgunes et al., 2009; Purdie & Hattie, 1996; Rautopuro & Väisänen, 2003). Learning practices are methods that a learner uses to improve their understanding, integration, and retention of new information in the learning process (Cross & Steadman, 1996). High achievers report a greater use of learning strategies than low achievers (Andrews, 1990; Dunn et al., 1995; John & Michael, 2018; Klavas, 1994; Pintrich & Schrauben, 1992), although these practices may vary among students (Ablard & Lipschultz, 1998). The use of certain learning practices is said to be related to interest in learning, and thus would improve students’ understanding or performance (Brush, 1997; Christou & Dinov, 2010; House, 2003, 2005).

Several research findings which analyze the association between learning practices and performance show that there exists a significant relationship between them (Christou & Dinov, 2010; Hassanbeigi et al., 2011; Montaque & ve Bos, 1990). Zimmerman (1989, 1990) listed some of the self-regulated learning practices which are related to students’ academic performance:

1) self-evaluating, i.e., students assessing the quality of their own work
2) organizing and transforming, i.e., students manipulating content to improve their learning
3) goal setting, i.e., students setting large and small related objectives and mapping out a process to achieve them
4) information seeking, i.e., students finding information from academic sources rather than from social resources.

Schau (2003) developed the Survey-of-Attitudes-toward-Statistics (SATS-36) scale to capture and examine students’ attitudes towards learning statistics in a course. SATS-36 enables educators to assess which component of students’ attitudes would need attention and require improvement. One of the six components, named “effort” consisting of 4 items, measures the amount of time students put in to learn statistics.

Eccles and colleagues (Eccles & Wigfield, 2002; Wigfield & Eccles, 2000; Wigfield et al., 2006), in relation to the expectancy-value theory, too suggest that an individual’s expectations for success and subjective task values will influence performance choices, directly or indirectly. Subjective task values refer to the “quality of the task that contributes to the increasing or decreasing probability that an individual will select it” (Eccles, 2005, p. 109). Moreover, if students “have high expectations of success but do not value a task at all (mentally assigning it a “0” value), then [they] will not feel motivated at all. Likewise, if [students] value a task highly but have no expectation of success about completing it (assigning it a “0” expectancy), then [they] also will not feel motivated at all” (Expectancy-Value Theory, n.d.).

Hence, learning practices do have significant influence on students’ attitudes towards the lesson which also affect their performance (Çalışkan & Kılınç, 2012; Habók & Magyar, 2018; Sirmaci, 2010; Çetingöz & Özkal, 2009).
A total of 596 students at a Malaysia public university participated in the study voluntarily. The respondents were systematically split into two random halves. The first sub-sample \((n_1 = 298)\) comprised 85% undergraduate students. This sub-sample was used to identify the underlying facets of *sejahtera* living. The second sub-sample \((n_2 = 298)\), also consisting of mainly undergraduate students (79%) was used for cross-validation. The procedure tested the stability and replicability of the underlying factors extracted from the first sub-sample. Cross-validation reduces the prospect of capitalizing on chance in the extraction of reliable and stable factors. The sample size of 298 for each analysis was deemed adequate for an exploratory factor analysis since the number of observations per item exceeded the threshold of 5:1.

**Influence of instructors’ teaching practices on students’ performance, attitudes toward statistics and learning practices.**

Past research has demonstrated that students’ academic performance is not only influenced by their learning practices but also by the teaching practices of their instructors throughout the course. A number of research has shown that instructors have a substantial impact on students’ performance (Chetty et al., 2014; Ganyaupfu, 2013; Yousef, 2017). Teaching practices vary across lecturers—some instructors may prefer direct instructional methods (i.e., lecturing, demonstrating and chalk-and-talk), while others may choose to employ strategies that are more student-centred (i.e., discussion, peer teaching, cooperative learning, etc.). Some instructors may be prone to employing rote learning (i.e., memorizing information), while others may emphasize understanding and the application of knowledge. Research has found that teaching practices both have a positive effect on student performance (Kennedy & Tay, 1994) and are a significant positive correlate of the construct (Onn, 1999).

Teaching basic statistical concepts is indeed a great challenge for many instructors as they need to be able to deliver the concepts in a way that their students can understand, especially at the undergraduate introductory level. A majority of students are exam-oriented; hence, instructors need to explicate the rationale of learning statistics to increase students’ motivation to master the knowledge and not only to satisfy the university or course requirements. Instructors should also prioritize the setting of clear objectives around which coherent lessons can be developed so that their teaching can be more effective (Umugiraneza et al., 2018). It is vital that the teaching practices used help students to understand statistical concepts well, so that not only can they perform well in their statistics courses, but they can also develop sound statistical literacy.

Active learning strategies have been shown to develop statistical reasoning in students. These strategies include group projects that require students to design a study, collect and analyze data, interpret their results, write a coherent and well-argued report, and share their findings in an oral presentation (Smith, 1998). It is commonly accepted that students always learn best when they are actively engaged in working on real-world problems (Sole & Weinberg, 2017).

Onwuegbuzie (2000) voiced a valid concern that non-cognitive variables such as students’ attitudes, feelings, beliefs and perceptions may counteract the learning atmosphere
that statistics instructors attempt to create. Instructors’ attention to students’ perspectives is needed to make statistics an interesting subject. Ncube and Moroke (2015) listed some recommendations to develop students’ learning interest and help them perform better in a statistics course. These include more exercises after each chapter, group assignments and presentations on how statistics can be integrated or applied in a job setting, use of statistical software to solve practical questions, and quizzes. Schau (2003) also noted the importance of student motivation and the need to use statistical thinking and statistical knowledge appropriately. It is very important to instill interest in learning statistics and make students understand statistics thoroughly so that they can perform well. Teaching practices have been found to exert a significant effect on students’ attitudes in several studies (Hannafin & Scott, 2001; Kreijns et al., 2007; Meletiou-Mavrotheris et al., 2007). Apart from that, instructors’ instructional practices also have been found to affect students’ learning practices (Andrews, 1990; Dunn et al., 1995; Klavas, 1994). Felder (1993) established that the alignment between students’ learning practices and the instructor’s teaching practices leads to better recall and understanding.

**Influence of students’ attitudes toward statistics on their performance**

The attitudes that students show towards learning a subject also have a major impact on their performance (Christou & Dinov, 2010; Evans, 2007). Attitudes as defined by Eagly and Chaiken (2007) is “an individual’s propensity to evaluate a particular entity with some degree of favorability or unfavorability” (p. 2). In 1980, Roberts and Bilderback developed the Statistics-Attitudes-Survey (SAS) followed by Wise (1985) who developed the Attitudes-Toward-Statistics (ATS) survey. Both surveys were developed to measure students’ attitudes towards statistics. To date, the most widely and commonly used instruments are the SATS-28 and SATS-36 by Schau et. al. (1995) and Schau (2003). The SATS-28 consists of a four-component structure that measures affect, cognitive competence, value, and difficulty. Later two more components were added, which are effort and interest, in the SATS-36.

There is an increasing body of evidence to support the conviction that students’ attitudes toward statistics affect their course enrolment, persistence, performance and the overall environment in the class (Hilton et al., 2004). Schau (2003) discovered that students’ attitudes toward statistics were positively related to their performance in statistics. Since students’ attitudes toward statistics have been shown to be related to student performance in statistics courses (Roslí & Maat, 2017; Saidi & Siew, 2019; Schau et al., 2012; Shultz & Koshino, 1998), it is hence believed that students’ negative attitudes toward statistics would present a significant obstacle for their effective learning of statistical content and skills (Mills, 2004).

According to Gal et al. (1997): students’ attitudes toward statistics may affect the extent to which they will develop useful statistical thinking skills and apply what they have learned outside the classroom. Presumably, poor attitudes will lead to poor skills. Baker (1988) also argued that in any learning situation, attitudes are considered to be a fundamental or an input variable, as well as an output or outcome variable. Therefore, it is important for researchers to thoroughly study the attitudes students have toward statistics and their relationship with performance so that interventions can be taken to increase their learning of this important course.
METHODOLOGY

Survey Respondents

First year students enrolled in introductory statistical courses from five Malaysian public universities participated in the study. The courses were similar in terms of the syllabus content, and all respondents were exposed to the same basic statistical concepts, with a slight variation in the treatment of the concepts. Students’ learning dissimilar concepts were excluded from being included in this study. Subsequently, a total of 416 students from four tertiary institutions made up the sample for this study (UiTM=113, UPM=144, UIA=81, USM=78). Kline (2011) stated that a sample size of 200 or more is necessary to obtain trustworthy results when structural equation modeling (SEM) is used in data analysis. Also the total of 416 students exceeded the recommended sample size for advanced multivariate statistical techniques, such as SEM (Tabachnick & Fidell, 2007).

Research Instruments

This study used five survey instruments that were developed in three phases: (1) item generation and theme development, (2) respondents’ feedback and (3) pilot testing. The instruments used are summarized in Table 1:

Table 1
Research Instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Construct</th>
<th>No of Items</th>
<th>Scaling</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Students’ Perceived Ability in Selected Basic Statistical Concepts Questionnaire (PASQ)</td>
<td>Students’ beliefs in their ability to understand and answer questions on statistical concepts</td>
<td>30</td>
<td>5-point agreement scale ranging from Strongly Disagree (1) to Strongly Agree (5).</td>
</tr>
<tr>
<td>3) Instructors’ Teaching Practices in Statistics Questionnaire (TPSQ)</td>
<td>Instructor’s teaching practices that develop students’ conceptual understanding in Statistics</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>4) Students’ Learning Practices in Statistics Questionnaire (LPSQ)</td>
<td>Students’ learning practices throughout the statistics course</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>5) Multiple Choice Questions on statistical concepts (adapted from DelMas et al., 2007) (MCQ30)</td>
<td>Students’ statistical competency and conceptual knowledge and understanding of basic statistical concepts.</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>
Data Collection

Permission was sought from the relevant heads of the departments offering the introductory statistics courses. However, only six instructors from four institutions agreed to allow their students to participate in the study, namely Universiti Teknologi MARA Malaysia (UiTM), Universiti Sains Malaysia (USM), Universiti Putra Malaysia (UPM) and the International Islamic University Malaysia (IIUM). The final sample comprised students who enrolled in the following courses: ECON 1140 Statistical Methods (IIUM), MGM3162 Business Statistics (UPM), ACT3111 Statistics for Accounting and Finance (UPM), QMT 181 Introduction to Statistics (UiTM) and MAT 161 Elementary Statistics (USM). These courses included all of the topics tested in the MCQ30—the instrument used in the study to measure students’ understanding of statistical concepts (i.e., student performance).

The SATS questionnaire was distributed at the beginning of week 1 of the semester. Students were given 10 minutes to complete the SATS. The PASQ and MCQ30 were distributed in week 7 of the semester, after all the topics had been taught by the instructors. The PASQ and the MCQ30 were administered separately to ensure that neither one influenced students’ responses to the other. The PASQ questionnaire was administered first before the test (MCQ30). The total time given for students to complete the questionnaire and the MCQ30 was 40 minutes. The TPSQ and LPSQ were distributed towards the end of the semester at the end of the lesson and the time given was 10 minutes.

Data Analysis Procedure

The MCQ 30 test was measured by the total raw scores based on each correct answer (i.e. 1 mark for a correct answer and 0 mark for an incorrect answer), which were subsequently transformed into interval-scaled person measures using the basic Rasch Model, as implemented by Winsteps version 3.63.

The factorial validity of the model (Figure 1) was established by testing the fit of the measurement model to the data based on goodness-of-fit indices. Three statistical software (SPSS 18.0, AMOS 18.0, and WINSTEPS 3.63.0) were used in the data analysis process. SPSS18.0 was used to analyze the preliminary data and provide demographic information. AMOS 18.0 was used to test the measurement model through Confirmatory Factor Analysis (CFA) and to test the structural model. Each student’s responses to the test and questionnaires were checked to make sure that there were no missing values during data entry in SPSS 18.0. Winsteps 3.63.0, a Rasch Model software was used to assess the reliability and validity of the instruments and to generate linear measures in logits (log odd units) to fit the proposed model. Interval scaled person measures were used for all the constructs.
RESULTS

Confirmatory Factor Analysis of the Scales

The Confirmatory Factor Analysis (CFA) for each scale (perceived ability, attitudes, learning practices and teaching practices), shows that the model fit measures of CFI, TLI, GFI, AGFI and RMSEA for Perceived Ability and Attitudes fail to meet the criteria for good fit (Table 3). Modifications were then made based on the modification index resulted from AMOS. For Perceived Ability, the items from types of data and data representation were combined into one construct, named data presentations. For Attitudes, item 20 and item 23 (cognitive competence items) and item 17 (difficulty item) were deleted and the remaining items from affect and cognitive competence were combined into a single construct, named affect_cognitive.

Table 3
Goodness of fit measures for perceived ability, attitudes, learning practices and teaching practices

<table>
<thead>
<tr>
<th>Goodness of Fit Measures</th>
<th>P value (P ≥ 0.05)</th>
<th>Ratio (2 or less)</th>
<th>CFI (0.90 and above)</th>
<th>TLI (0.90 and above)</th>
<th>GFI (0.95 and above)</th>
<th>AGFI (0.90 and above)</th>
<th>RMSEA (0.08 or less)</th>
<th>AIC (Smaller values suggest a good fitting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Ability</td>
<td>0.000</td>
<td>10.231</td>
<td>0.987</td>
<td>0.962</td>
<td>0.975</td>
<td>0.873</td>
<td>0.149</td>
<td>36.461</td>
</tr>
<tr>
<td>Attitudes</td>
<td>0.000</td>
<td>71.801</td>
<td>0.949</td>
<td>0.848</td>
<td>0.854</td>
<td>0.270</td>
<td>0.413</td>
<td>159.602</td>
</tr>
<tr>
<td>Teaching Practices</td>
<td>0.172</td>
<td>1.760</td>
<td>0.999</td>
<td>0.998</td>
<td>0.996</td>
<td>0.979</td>
<td>0.043</td>
<td>19.519</td>
</tr>
<tr>
<td>Learning Practices</td>
<td>0.881</td>
<td>0.022</td>
<td>1.000</td>
<td>1.006</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>10.022</td>
</tr>
</tbody>
</table>

Notes: Criteria for Fit: Chi-Square test P ≥ 0.05; GFI ≥ 0.95; RMSEA ≤ 0.08; AGFI ≥ 0.90; CFI ≥ 0.90; TLI ≥ 0.90; Relative Chi-Square ≤ 2; AIC - Smaller values suggest a good fitting model

The Perceived Ability CFA model and the Attitudes CFA model based on the newly modified constructs suggest that both models fit the data well and that the models fail to be rejected. The revised CFA model yielded goodness of fit measures with lower AIC compared to the initial CFA model for both constructs (Table 4). The AIC which is a comparative measure of fit with lower values indicates a better fit and thus, the re-specified model is considered a better model compared to the initial model (Schermelleh-Engel, Moosbrugger & Müller, 2003).

Table 4
Goodness of fit measures for perceived ability and attitudes after modifications

<table>
<thead>
<tr>
<th>Goodness of Fit Measures</th>
<th>P value (P ≥ 0.05)</th>
<th>Ratio (2 or less)</th>
<th>CFI (0.90 and above)</th>
<th>TLI (0.90 and above)</th>
<th>GFI (0.95 and above)</th>
<th>AGFI (0.90 and above)</th>
<th>RMSEA (0.08 or less)</th>
<th>AIC (Smaller values suggest a good fitting)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Ability</td>
<td>0.529</td>
<td>0.396</td>
<td>1.000</td>
<td>1.002</td>
<td>0.999</td>
<td>0.996</td>
<td>0.000</td>
<td>10.396</td>
</tr>
<tr>
<td>Attitudes</td>
<td>0.912</td>
<td>0.012</td>
<td>1.000</td>
<td>1.002</td>
<td>1.000</td>
<td>1.000</td>
<td>0.000</td>
<td>10.012</td>
</tr>
</tbody>
</table>
Having established the best fitting measurement models for all the constructs, the convergent and discriminant validity were calculated to quantify construct validity. Convergent validity of each factor was tested by examining the standardized factor loadings (Table 5). According to Hair et al. (2010), factor loading values more than 0.5 and above 0.7 are considered good for a construct. All the constructs were deemed valid and reliable as they meet the above-given criteria for factor loadings. As all items produced values greater than 0.5 in the analyses conducted (i.e., convergence was achieved), the covariance matrix was assumed to be non-singular and free from multicollinearity.

Convergent validity can also be calculated using the Average Variance Extracted (AVE) as proposed by Fornell and Larcker (1981), where the total of squared multiple correlations are divided by the number of subscales. The guideline is that the AVE value should be greater than 0.5, meaning more than half of the variances are observed (Hair et al., 2010). Examining the AVE values in Table 6, it was found that all of these values are over 0.50. Hence, based on the standardized factor loadings and the AVE calculation, convergent validity was confirmed.

**Table 5**  
Standardized factor loadings and Average variance extracted (AVE) for perceived ability, attitudes, teaching practices and learning practices

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Items</th>
<th>Standardized Regression Weight (Loadings)</th>
<th>Squared Multiple Correlation</th>
<th>Total Squared Multiple Correlation</th>
<th>Average Variance Extracted (AVE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Ability</td>
<td>Data Presentations</td>
<td>0.893</td>
<td>0.798</td>
<td>2.502</td>
<td>0.834</td>
</tr>
<tr>
<td></td>
<td>Measures of Center</td>
<td>0.933</td>
<td>0.870</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measures of Spread</td>
<td>0.913</td>
<td>0.834</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitudes</td>
<td>Affect_Cognitive</td>
<td>0.981</td>
<td>0.963</td>
<td>2.853</td>
<td>0.951</td>
</tr>
<tr>
<td></td>
<td>Value</td>
<td>0.961</td>
<td>0.923</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difficulty</td>
<td>0.983</td>
<td>0.967</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teaching Practices</td>
<td>Pedagogical Approach</td>
<td>0.948</td>
<td>0.900</td>
<td>3.324</td>
<td>0.831</td>
</tr>
<tr>
<td></td>
<td>Engaging Students in Learning 1</td>
<td>0.957</td>
<td>0.915</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Engaging Students in Learning 2</td>
<td>0.762</td>
<td>0.580</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Use of Technology</td>
<td>0.964</td>
<td>0.929</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning Practices</td>
<td>Regular Practices</td>
<td>0.905</td>
<td>0.819</td>
<td>1.86</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>Self-Determination</td>
<td>0.645</td>
<td>0.416</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Source of Reference</td>
<td>0.790</td>
<td>0.625</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The discriminant validity for the four scales was evident as the AVEs were found to be greater than the squared correlations between any two dimensions (Table 6). The squared correlations between *Attitudes* and *Learning Practices* produced a value which is relatively close to the AVE value of *Attitudes* and AVE value of *Learning Practices*, but it is still below the threshold limit. Thus, the discriminant validity for the four scales is supported.
Table 6
Discriminant validity for perceived ability, attitudes, teaching practices and learning practices

<table>
<thead>
<tr>
<th>Scales</th>
<th>Perceived Ability</th>
<th>Attitudes</th>
<th>Teaching Practices</th>
<th>Learning Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Ability</td>
<td>0.8340</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitudes</td>
<td>0.0529</td>
<td>0.9510</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teaching Practices</td>
<td>0.0010</td>
<td>0.0018</td>
<td>0.8310</td>
<td></td>
</tr>
<tr>
<td>Learning Practices</td>
<td>0.0004</td>
<td>0.5184</td>
<td>0.0135</td>
<td>0.6200</td>
</tr>
</tbody>
</table>

Note: Diagonal values are AVE and off-diagonal values are squared correlations

Assessment of the Assumption of Normality

To test the assumption of normality, the univariate skew and kurtosis were examined using the suggested cut-offs of [3.0] and [10.0], respectively. The skewness of the items ranged from −0.771 to 0.635 and the values for kurtosis ranged from 0.064 to 4.687. Kline’s (2011) suggestion that only variables with skew index absolute values greater than 3 and kurtosis index absolute values greater than 10 are of concern, none of the variables in this analysis has problematic levels of skewness or kurtosis. Thus, the data were sufficiently univariate normally distributed. West, Finch and Curran (1995) recommended concern if skewness is more than 2 and kurtosis is more than 7. If the univariate distributions are nonnormal, then the multivariate distribution will be nonnormal. From the analysis, the univariate skewnesses and kurtoses fall into acceptable ranges of normality (Harlow, 1985).

A Bollen-Stine bootstrap was run in AMOS 16.0 to confirm that the overall model worked satisfactorily. For non-normal data, Bollen-Stine bootstrap can provide the correct p-values for the chi-square statistic to assess overall model fit, rather than the usual maximum likelihood-based p-value to assess overall model fit. Using a conventional significance level of 0.05, the model will be rejected if the p-value is smaller than 0.05. If the p-value is larger than 0.05, the model will not be rejected (the model is accepted, and thus conclusion can be made that the model fit the data well) (Bollen & Long, 1993; Bollen & Stine, 1992). Testing the null hypothesis that the model is correct, using number of bootstrap samples of 500 (Cheung & Lau, 2008), the results yielded Bollen-Stine bootstrap, p = 0.369 (Figure 2). This result confirmed that the model was correct and would not be rejected.
Figure 2
Bollen-Stine bootstrap

Testing the null hypothesis that the model is correct, Bollen-Stine bootstrap p = .369

Estimation of the Hypothesized Structural Model

Next, the structural model based on the hypotheses was tested. The specified structural model produced a good fit to the data as indicated by the goodness of fit indices (Figure 3). Model fit measures of CFI=0.999, TLI=0.998, GFI=0.973 and the RMSEA=0.015 meet the criteria for fit with p-value equal 0.269. The value of the relative Chi-square ($\chi^2$/df) equals 1.096 which is less than 2, and the value of the adjusted goodness-of-fit index (AGFI) equals 0.961, which is more than 0.95, also indicated that the model fitted the data well and that the model failed to be rejected.

Figure 3
Structural model (Standardized factor loadings and regression estimates with selected fit indices)
The summary of the hypotheses testing results are shown in Table 7 and the detailed results of the $R^2$ values (effect size) are shown in Table 8.

The hypotheses being tested in numerical order are the effects of: Perceived Ability on Performance; Learning Practices on Performance; Teaching Practices on Performance; Attitudes on Performance; Perceived Ability on Attitudes; Learning Practices on Attitudes; Teaching Practices on Attitudes; Teaching Practices on Learning Practices.

Based on the results in Table 7, it is evident that students’ Perceived Ability in statistics has a direct effect on students’ Performance and a direct effect on students’ Attitudes toward statistics. Instructors’ Teaching Practices is also positively related to the students’ Learning Practices. The confidence intervals for these paths do not contain the value zero (Hair et al., 2017). Furthermore, the results of the effect size (Table 8), suggest that perceived ability exhibited an acceptable effect size on Performance ($f^2 = 0.0449$) and on Attitudes ($f^2 = 0.0541$). So does the effect size of Teaching Practices on Learning Practices ($f^2 = 0.0132$). These values are all above 0.002.

Cohen (1988) established that the effect size, $f^2$ values of 0.02, 0.15 and 0.35 are to be classified as small, medium and large. However, Aguinis, Beaty, Boik, and Pierce (2005) identified a median effect size of .002 and has also shown that the average effect size in tests of moderation is only 0.009. Whereas, Kenny (2015) suggests a more realistic but still optimistic standard for effect sizes might be 0.005, 0.01, and 0.025 for small, medium, and large, respectively, given the Aguinis et al. (2005) review. Chin, Marcolin, and Newsted (2003) supported that small effect size is important and can be meaningful. The effect sizes in moderation tests are, on average, lower than those indicated by Cohen (1988), hence the most conservative choice is to use lower effect sizes than expected (Aguinis et al., 2005; Perugini, Gallucci, & Costantini, 2018).

There exists no relationship between students’ Learning Practices and students’ Attitudes toward statistics. Instructors’ Teaching Practices were also found to have no direct effect on students’ Attitudes toward statistics. The results of confidence intervals, based on the bootstrapping method (subsamples 500) used to analyze the path coefficient significance further confirm on the findings (Davison & Hinkley, 1997; Efron & Tibshirani, 1993; Hair et al., 2017).

### Table 7

**Results of Hypothesis Testing**

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Structural Relation</th>
<th>Standard Regression Weights</th>
<th>t-value</th>
<th>Confidence Intervals 2.5%</th>
<th>Confidence Intervals 97.5%</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>Performance ← Perceived Ability*</td>
<td>0.206</td>
<td>4.023</td>
<td>0.105</td>
<td>0.287</td>
<td>0.000</td>
</tr>
<tr>
<td>H2</td>
<td>Performance ← Learning Practices</td>
<td>0.007</td>
<td>0.137</td>
<td>-0.093</td>
<td>0.096</td>
<td>0.891</td>
</tr>
<tr>
<td>H3</td>
<td>Performance ← Teaching Practices</td>
<td>-0.047</td>
<td>-0.958</td>
<td>-0.143</td>
<td>0.088</td>
<td>0.338</td>
</tr>
<tr>
<td>H4</td>
<td>Performance ← Attitudes</td>
<td>-0.019</td>
<td>-0.381</td>
<td>-0.103</td>
<td>0.077</td>
<td>0.704</td>
</tr>
<tr>
<td>H5</td>
<td>Attitudes ← Perceived Ability**</td>
<td>0.228</td>
<td>4.589</td>
<td>0.122</td>
<td>0.32</td>
<td>0.000</td>
</tr>
<tr>
<td>H6</td>
<td>Attitudes ← Learning Practices</td>
<td>-0.068</td>
<td>-1.306</td>
<td>-0.15</td>
<td>0.045</td>
<td>0.192</td>
</tr>
<tr>
<td>H7</td>
<td>Attitudes ← Teaching Practices</td>
<td>0.041</td>
<td>0.832</td>
<td>-0.054</td>
<td>0.137</td>
<td>0.405</td>
</tr>
<tr>
<td>H8</td>
<td>Learning Practices ← Teaching Practices *</td>
<td>0.114</td>
<td>2.140</td>
<td>0.018</td>
<td>0.214</td>
<td>0.032</td>
</tr>
</tbody>
</table>

*Note: t-value >2.58 (p-value <0.01**), t-value >1.96 (p-value <0.05*)
Table 8

Effect Size

<table>
<thead>
<tr>
<th>Structural Relation</th>
<th>( R^2 ) included</th>
<th>( R^2 ) excluded</th>
<th>( f^2 )</th>
<th>( f^2 ) (Cohen, 1988)</th>
<th>( f^2 ) (Aguinis et al., 2005)</th>
<th>( f^2 ) (Kenny, 2015)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance ← Perceived Ability</td>
<td>0.043</td>
<td>0.000</td>
<td>0.0449</td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
</tr>
<tr>
<td>Performance ← Learning Practices</td>
<td>0.043</td>
<td>0.043</td>
<td>0.0000</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Performance ← Teaching Practices</td>
<td>0.043</td>
<td>0.040</td>
<td>0.0031</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Performance ← Attitudes</td>
<td>0.043</td>
<td>0.043</td>
<td>0.0000</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Attitudes ← Perceived Ability</td>
<td>0.058</td>
<td>0.007</td>
<td>0.0541</td>
<td>Small</td>
<td>Medium</td>
<td>Large</td>
</tr>
<tr>
<td>Attitudes ← Learning Practices</td>
<td>0.058</td>
<td>0.054</td>
<td>0.0042</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Attitudes ← Teaching Practices</td>
<td>0.058</td>
<td>0.057</td>
<td>0.0011</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Learning Practices ← Teaching Practices</td>
<td>0.013</td>
<td>0.000</td>
<td>0.0132</td>
<td>None</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

DISCUSSION

There are many studies that focused on the teaching and learning of statistics over the years as statistics education is fast becoming a research area of increasing interest among researchers. The importance of developing students’ statistical literacy at the undergraduate level remained the primary issue discussed across the globe. This study, sought to determine the influence of students’ learning practices, lecturers’ teaching practices, students’ perceived ability, students’ attitudes towards statistics on students’ conceptual understanding of basic statistical concepts as measured by their performance on a 30-item MCQ test.

The results of analysis showed that students’ perceived ability has a direct and positive effect on students’ performance in basic statistical concepts. Several studies support this finding, which showed that students’ perceived ability is associated with performance (House, 2006; Jaiswal & Choudhuri, 2017; Lenaburg, 2007; Lynch, 2002; Obilor, 2012; Tenaw, 2013). Students’ perceived ability or self-efficacy influences the tasks students choose to learn and the goals they set for themselves. Perceived ability also affects students’ level of effort and persistence when learning difficult tasks. If they hold the belief that they are able to accomplish a particular task, they will be more likely to attempt and persist in that task (Schmidt & Shumow, 2011).

Students’ perceived ability was also found to have a direct effect on students’ attitudes towards statistics. This finding coincides with the studies by Dempster and McCorry (2009), and Kloosterman et al. (1996) who found strong support for the relationship between students’ perceived ability and their attitudes where there exists a relation between students’ attitude and their perceived ability at the beginning of the course and that certain beliefs do motivate or
demotivate students. Hence, students’ perceived ability has implications on their motivation levels and performance.

Self-efficacy or perceived ability and attitudes are factors that have been found to be related to students’ performance. Conversely, in this study, attitudes have no direct relationship with students’ performance in understanding basic statistical concepts. The finding concerning the relationship of attitudes and performance were contrary to the findings of some previous studies (Chiesi & Primi, 2010; Christou & Dinov, 2010; Sorge & Schau, 2002; Tremblay, Gardner, & Heipel, 2000). Conflicting results might be due to differences in the population of interest (i.e. American sample would produce different findings from an Asian sample).

Learning practices include effort regulation, help seeking, and peer learning (Nisbet & Shucksmith, 1986; Pintrich, 2000) as well as task absorption (Elliot, Murayama, & Pekrun, 2011) to enhance student learning. According to the empirical data garnered in this study, learning practices are not directly related to students’ attitudes towards students’ performance in basic statistical concepts. This finding is also contrary to the findings of previous studies by Brush (1997) and House (2003, 2005). In few studies, learning practices has been found to be positively related to performance (Christou & Dinov, 2010; Diseth et al., 2010; Hassanbeigi et al., 2011; Pintrich, Smith, Garcia, & McKeachie, 1993). Onwuegbuzie (2001) discovered that learning practices does affect students’ performance where students who prefer to learn in a co-operative learning groups do not perform well compared to their counterparts. However, from this study, students’ learning practices were found to have no direct influence on students’ performance in basic statistical concepts which was in line with studies conducted by Rautopuro and Väisänen (2003), Awang, Abd Samad, Mohd Faiz, Roddin, and Kankia (2017) and Gappi (2013). Different instrumentation and differences in the way variables are measured for the learning practices would have caused the difference in the findings.

Results from the analysis also showed that teaching practices do not have a direct influence on students’ attitudes and their performance in basic statistical concepts. This contradicts previous studies by Yousef (2017), Ganyaufu (2013), Brush (1997), Diseth, Pallesen, Brunborg, and Larsen (2010), and Onn (1999) where there exists a relationship between teaching practices and performance. Teaching practices was also found to have no effect on students’ attitudes and were contrary to the findings of previous studies (Hannafin & Scott, 2001; Kreijns et al., 2007; Meletiou-Mavrotheris et al., 2007). The differences in respondents’ characteristics, settings and research instruments are postulated to play a role to the differing findings. Nonetheless, it was found that teaching practices do affect students’ learning practices. Previous research also shows that teaching practices that match students’ learning practices can improve their performance significantly while a mismatch can result in poor students’ performance (Andrews, 1990; Dunn, Griggs, Olson, Gorman, & Beasley, 1995; Giordano & Rochford, 2005; Klavas, 1994).

Future research should consider examining the impact of learning practices on students’ perceived ability and the impact of teaching practices on students’ perceived ability, as perceived ability is related to both attitudes and performance.
CONCLUSION

In recent years, there has been extensive research regarding students’ understanding of basic statistical concepts for the development of statistical thinking, statistical literacy and statistical reasoning (Chance, DelMas & Garfield, 2004; Chance, 2002; DelMas, 2002; Gal, 2002; Garfield, 1995, 1999; Wild & Pfannkuch, 1999). This study examined the influence of students’ learning practices, lecturers’ teaching practices, students’ perceived ability, and students’ attitudes towards statistics on their understanding of basic statistical concepts. Results from the analysis provide some empirical evidence that students’ understanding in basic statistical concepts is mainly associated with their perceived ability, rather than their attitudes, learning practices and instructors’ teaching practices. In other words, students with low self-efficacy levels had low test scores; while students with high self-efficacy levels performed better on the test. Students’ attitudes are influenced by their perceived ability while teaching practices do affect learning practices. Students who perceived greater ability, have a higher sense of their own competency in the task given and have more positive attitudes toward learning statistics.

Nonetheless, further understanding of students’ learning practices and instructors’ teaching practices are needed to improve students’ understanding of basic statistical concepts and their performance in statistics, particularly. Future research should examine students’ perceived attitude, understanding and ability in introductory statistical concepts through a longitudinal study, to better understand the relationships between these constructs. It is also recommended that the instruments used in this study – MCQ30, PASQ, LPSQ and TPSQ – be administered to other similar populations to determine the generalizability of the instruments in measuring the target constructs. Future research should also include qualitative data collection methods to enhance the quantitative findings as qualitative approaches would give a complementary view of the learning and teaching of statistics.
REFERENCES


