*Developing Statistical Reasoning and Thinking Assessment for Engineering Students: Challenges and New Direction*

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**Abstract**
In this paper, an assessment for students' ability in critical thinking within statistics content is discussed. Despite instructors' awareness on critical thinking as one of essentials 21$^{st}$ century skills, it remains unclear about how to develop the instructional framework for teaching, learning and assessing critical thinking in statistics domain. Moreover, there is an urgency to reform statistics classroom include; the way instructor teach statistics, the way students learn statistics and how to assess statistics learning outcomes to support critical thinking. In order to identify and design the critical thinking framework, the objectives of this study are; 1. To highlights issues related to assessing statistical reasoning and thinking for educators instructional strategies. 2. To provide a framework for assessing statistical reasoning and thinking. 3. To develop instructional design for teaching thinking in statistics classroom. The implications for classroom teaching will be explored through final examination results. The challenges are identified and new directions for promoting critical thinking in statistics classroom are identified.

Keywords: critical thinking, higher order thinking, statistics education, thinking routines

**Introduction**

Improving teaching and learning statistics has been extensively discussed in several literatures (e.g., Ben-Zvi & Garfield, 2005; Chance, 2002; English & Watson, 2015; Garfield & Chance, 2000; Garfield & Ben-Zvi, 2007; Jones et al., 2001; Pfannkuch & Wild, 2004; Sedlmeier, 2000; Tishkovskaya & Lancaster, 2012) and the research in statistics educations is continuously demanding especially in the current technology advancement and new challenge such as in the area of data science and big data.

Teaching statistics with emphasize on statistical thinking, use more data and concepts, and fostering active learning were proposed by Cobb (1992). Such areas appear particularly important with the exponential increase demand for data analytics due to data collection capabilities in the era of big data. For such reason, the traditional teaching and learning practices are unpromising in helping student's to think with data (McNamara, 2015). For example, Finzer (2013) suggested integration of data science into content area can be important consideration to inculcate learners with data as the habits of mind. The role of data is also discussed by Neuman et al. (2013) in which real-life data is important for illustrating statistical concepts, practice calculations, and application of statistics.

Statistical investigation is known as the process of conducting investigations from data collection, to exploring data, to statistical inference, to drawing appropriate conclusions (Chance et al., 2015). Moore (1990) pointed out that data should be viewed as numbers with context. The interpretation of statistical result should be delivered into its context or else students are not learning the process of statistical investigations. Moreover, integrating context of a problem with its statistical results increase the opportunities of students to interact, interpret and draw conclusions about data (Pfannkuch & Wild, 2003).

Learning statistics means learning to communicate using the statistical language, solving statistical problems, drawing conclusions, and supporting conclusions by explaining the reasoning behind them (Garfield, 1995). One reform has focused on content and pedagogy, shifting the focus from computation and procedures to an emphasis on statistical reasoning and thinking (Moore, 1997).

Clarifying statistical learning outcomes can help statistics instructors better to design and use appropriate assessment to align with the learning goals highlighted and value by current research in statistics education. These outcomes refer to statistical literacy, statistical reasoning and statistical thinking. In this paper, an assessment of students' ability in statistical reasoning and thinking skills are presented and discussed. For this purpose a selected topic for final examination evaluation is constructed according to framework developed by DelMas (2002b).

**Problem Statement**

The need to reform statistics classroom includes; the way instructor teach statistics, the way students learn statistics and how to assess statistical learning outcomes specifically statistical reasoning and thinking. In addition to using lecture-and-listen format predominantly, many such courses heavily rely on having students do assignments in textbooks or in computer labs, and take multiple choice or traditional

tests emphasizing formulae, rote memorization skills and procedural knowledge, as opposed to conceptual knowledge of statistics (Garfield, 1995).

This is why students often see the content as a sequential set of tools and procedures and do not see how the concepts are interrelated (Garfield & Ben-Zvi, 2009). Ben-Zvi & Garfield (2015) highlighted that the main argument about statistics education is the traditional approaches of teaching statistics focus on procedures and computations skills which do not expose students to reason and think statistically. For example, as presented by Friel, et al. (2006) many students are taught mean, median, mode, and graphs with an emphasis on how to construct them rather than how to use them to think with data. An emphasis on students' development of conceptual understanding rather than a focus on procedural knowledge are highlighted by Garfield & Chance (2002).

On the other hand, higher order thinking skill requires learner to embrace critical, reflective, metacognitive and creative thinking. Specifically in statistics education, reflecting about data, interpreting it and making decision are one of essential processes in statistical investigations. Therefore, using data to extract meaning and insight about real context and real situation should be an important outcome in statistics classroom. However, it can only achievable if the instructors are motivated to go beyond procedures and computations.

Hence, we believed that the ability to develop statistical investigations process through reasoning and thinking are more crucial rather than ability to grasp merely on the statistical procedures. Currently, such skills are not reflected as the learning outcomes in a statistics classroom. We would expect greater learning outcomes as suggested in Friedrich et al. (2000) to teach statistics that highlight reasoning, understanding and interpretation of data rather than merely computation of statistical formulas.

Assessment alone may not sufficient to inform instructor about students' disposition in statistical reasoning. Those with poor statistical reasoning disposition can still do well in final examination (Chance & Garfield, 2001). Therefore, an on-going research study is conducted in order to discover ways for developing effective culture of thinking in statistics classroom in transferring and strengthening statistical literacy skills, ability to think and reason statistically among engineering students at Universiti Malaysia Perlis. Therefore, to achieve the educational goal, the objectives of this study are; 1. To highlights issues related to assessing statistical reasoning and thinking for educators instructional strategies. 2. To provide a framework for assessing statistical reasoning and thinking. 3. To develop instructional design for teaching thinking in statistics classroom

**Statistical Literacy, Reasoning and Thinking**

The definition of statistical reasoning and thinking is not defined in common. There are a lot of definitions given in the literatures. Among the definition is; it may be defined as the way people reason with statistical ideas and make sense of statistical information (Garfield, et al. 2003). To understand how statistical literacy, reasoning, thinking have been described in the literatures, we presented the definitions in the following sub-section.

### Statistical Literacy

"Statistical literacy is defined as the ability to interpret, critically evaluate, and if needed communicate about statistical information, arguments, and messages" (Gal, 2002, p.1). In Garfield et al. (2003) it includes "understanding words and symbols, being able to read and interpret graphs and terms" (p.3). Meanwhile, Wallman (1993) "argued that statistical literacy is the ability to understand and critically evaluate statistical results that permeate daily life, coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions" (as cited in Gal, 2002, p.2).

### Statistical Reasoning

"Statistical reasoning may be defined as the way people reason with statistical ideas and make sense of statistical information" (Garfield & Gal, 1999, p.2). It can be interpreted as ability to use sets of data for making interpretations, how to represent data, or summarizing data with statistical measures (Garfield et al., 2003). Garfied et al. (2003) added that connecting statistical concept such as measure of central tendency with spread would help to deepen understanding and increase ability to explain statistical process and interpret statistical results.

### Statistical Thinking

"Statistical thinking involves an understanding of why and how statistical investigations are conducted and the "big ideas" that underlie statistical investigations" (Garfield et al., 2003, p.8). Moreover, statistical thinkers should be able to solve a given problem or statistical study through analyzing, synthesizing and evaluating the results and critique (Garfield et al., 2003). Chance (2002) defined that statistical thinking is beyond the literacy and ability to reason such that the statistical process can be seen as a whole which include the capability of answering 'why', to understand the relationship and meaning of variation in a process.

Apart from the definition of statistical literacy, reasoning and thinking, an appropriate assessment of those skills are extremely important. The assessment methods are often focus on the application of correct formulas, correct statistical computations and the choice of graphical presentations as well as lack of evaluating statistics content with context (Garfield & Gal, 1999). Students' should be able to interpret statistical information or arguments. However, is not adequate if the questions constructed focus on "right or wrong", and therefore limited reflection on students' reasoning and thinking processes abilities (Gal & Garfield, 1997). Therefore, an appropriate assessment method are required for evaluating statistical reasoning, that reveal students' thinking as they choose and apply statistical tools, when they make sense of data, interpret results, and draw conclusions (Garfield & Gal, 1999).

Although statistical literacy, reasoning and thinking may best be assessed through classroom activities, communication with students (e.g., interviews or observations) or by examining students work from a statistics project, a well- prepared and designed paper-and-pencil instruments can be used to gather some limited indicators of students' nature of thinking process.

**Relationship between Statistical Literacy, Reasoning and Thinking**

The concepts of statistical literacy, reasoning, thinking can be interpreted as three instructional domains and can be overlap DelMas (2002b). DelMas (2002b) focused on what students can do with the content rather than the content itself. Figure 1 shows the three domains illustrated in DelMas (2002b). Statistical literacy plays an important foundation to statistical reasoning and thinking.
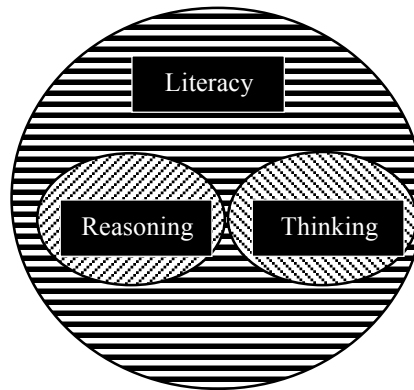


Figure 1: Outcomes of statistics education: Reasoning and thinking within literacy.

DelMas (2002b) proposed words used to distinguish the goals of statistical literacy (SL), reasoning (SR) and thinking (ST). The list of words is given by Table 1.

Table 1: List of words use to distinguish three instructional domains

| Basic Literacy | Reasoning | Thinking |
|---|---|---|
| Identify Describe Rephrase Translate Interpret Read | Why? How? Explain the process | Apply Critique Evaluate Generalized |

In the following section, we presented the revised Bloom's taxonomy. This taxonomy was used as the basis for developing assessments instruments. Our objective is to establish appropriate assessment instruments through combination of revised Bloom's taxonomy and SL, SR and ST skills.

**Revised Bloom's Taxonomy**

The revised Bloom's taxonomy by Anderson & Krathwohl (2001) as in (Forehand, 2010) used verbs instead of noun for the cognitive domain. The cognitive levels are as follows:

Table 2:  Revised Bloom's taxonomy for learning, teaching and assessing

| | |
|---|---|
| Remember | Retrieving, recognizing, and recalling relevant knowledge. |
| Understand | Constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining. |
| Apply | Carrying out or using a procedure through executing, or implementing. |
| Analyze | Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure or purpose through differentiating, organizing, and attributing. |
| Evaluate | Making judgments based on criteria and standards through checking and critiquing. |
| Create | Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing. |

**Comparative Thinking**

Higher possibility of  learning is expected when students are able to make comparisons Silver (2010).  According to Silver (2010) comparison technique helps students to strengthen their ability to recall and remember main idea through analyzing pairs of idea and capturing the similarities and differences. This method can be helpful in classroom situations such as introducing concepts or recall prior knowledge that is related to new content. There are four phases of compare and contrast strategy introduced by Silver (2010) for a classroom phase; there are description, comparison, conclusion, application.

The advantage of comparative thinking through capturing similarities and differences provides a deeper thinking about concepts and can be used to trigger questions which required students to reason and think critically. Therefore, question such as "*What is (are) evidence does (do) you have to support your conclusion?*" could develop thinking as a habit of mind and deepen their learning. Moreover, questioning technique improves engagement and the opportunities to reflect develop students' metacognitive skills.

In the following section, the assessment of SL, SR and ST within revised Bloom's taxonomy using similarities and differences method are discussed. The implications for improving classroom practices will be explored.

**Methodology**

In this study, a quantitative method was applied. Students' final examination scores served as indicators to evaluate their thinking process with respect to SL, SR, ST.

**Participants**

The participants were 1022 engineering students from eighteen engineering programs. The Engineering Statistics (EQT271) course is the only required statistics course. This course was scheduled during their second year of study.

**Instrumentation**

There were five topics in the subject; Basic to Engineering Statistics, Probability Distributions, Statistical Inference (Single and Two Populations), Analysis of Variance (ANOVA) (One-Way ANOVA, Randomized Complete Block Design, Two Factor Factorial Design) and the last chapter is Simple Linear Regression. The examination paper consists of five questions (Q1,Q2,Q3,Q4,Q5) and the composition of the examination component is 50%.

Table 3: Course outcomes (CO) and cognitive level based on revised Bloom's Taxonomy

| CO1 | Remember, Understand, Apply | Ability to understand, apply and explain the basic concepts of statistics. |
|---|---|---|
| CO2 | Remember, Understand, Apply, Analyze | Ability to solve problems using suitable statistical inference. |
| CO3 | Remember, Understand, Apply, Analyze | Ability to construct the model and analyze the result from ANOVA table and simple linear regression. |
| CO4 | Remember, Understand, Apply | Ability to apply the basic methodology of nonparametric statistics to solve engineering problems. |

Table 4: Topics evaluated in EQT271 final examination paper

| Question | Topic |
|---|---|
| Question 1 (Q1) | Simple Linear Regression |
| Question 2 (Q2) | Two-Way Analysis of Variance With Replication |
| Question 3 (Q3) | Randomized Complete Block Design |
| Question 4 (Q4) | Statistical Inference for Two Populations |
| Question 5 (Q5) | Non-Parametric Test |

To assess SL, SR, ST outcomes, we choose the topic of simple linear regression as shown in Figure 2.

**Question 1**
*[Soalan 1]*

The output of a certain product could get off-target as machine is used over long periods of time. Machine A and B are used to produce the products. The data of machines used, $x$ (in hours) and the off-target size, $y$ (in mm) are collected. Output 1.1 and Output 1.2 are the regression analysis performed to both data sets.

**Output 1.1: Regression Analysis for Machine A**

ANOVA Table:

| Source of Variation | df | SS | MS | F | p-value |
|---|---|---|---|---|---|
| Regression | 1 | 1.059 | 1.059 | 57.74 | 6.31E-05 |
| Residual | 8 | 0.147 | 0.018 | | |
| Total | 9 | 1.205 | | | |

Regression Coefficients:

| | Coefficients |
|---|---|
| Intercept | 0.024 |
| X1 | 0.045 |

**Output 1.2: Regression Analysis for Machine B**

ANOVA Table:

| Source of Variation | df | SS | MS | F | p-value |
|---|---|---|---|---|---|
| Regression | 1 | 0.817 | 0.817 | 99.37 | 8.69E-06 |
| Residual | 8 | 0.066 | 0.008 | | |
| Total | 9 | 0.883 | | | |

Regression Coefficients:

| | Coefficients |
|---|---|
| Intercept | 0.060 |
| X1 | 0.040 |

Figure 2: Questions designed to assess SL, SR, and ST were constructed using simple linear regression learning outcomes

Seven sub-questions or items were constructed based on given statistical problem (Question 1) as in Figure 2. Two different outputs from two types machines (Machine A and B) were given. From the given linear regression outputs, questions assessed students' SL, SR and ST skills are shown in Figure 3.

**Based on the Output 1.1 and 1.2, answer the following questions:**

(a) This statement *"The line describes by the regression equation attempts to minimize the number of points it touches"* is wrong. Write the correct statement.
(b) Compute $r^2$ for both regression analysis.
(c) Sketch the possible scatter plots for machine A and B data sets. Interpret the relationship between the variables.
(d) Is there any significance linear relationship between hours of machine used and the size of off-target at $\alpha = 0.10$ for machine A? Perform the appropriate hypothesis test and state your conclusion.
(e) Comment on the regression model adequacy for both machines.
(f) Determine when the product will be 2 mm off-target for both machines?
(g) Suggest which machine you want to use? Support your answer by evaluating your findings in (e) and (f).

Figure 3: Statistical literacy, reasoning and assessment

Therefore, we mapped each question based on the revised Bloom's Taxonomy given by Table 3.

| Question | Revised Bloom's Taxonomy | The expected outcomes: *Students should be able to:* |
|---|---|---|
| a | Understand | ***recognize*** that the statement is wrong based on the keywords *"minimize the number of points it touches"*.<br><br>***rewrite*** the correct statements by using the concept of least squares method. |
| b | Apply | ***compute*** of coefficient of determination. |
| c | Analyze<br><br>Apply | ***connect and extend statistical information*** using *Question b*, Output 1 and 2.<br><br>***interpret*** coefficient of determination. |
| d | Evaluate | ***perform hypothesis test*** and ***evaluate*** the result to make ***conclusion***. |
| e | Analyze<br><br>Evaluate | ***recognize, relate and compare*** statistical results provided by Output 1 and 2.<br><br>***evaluate*** appropriate statistical results and make conclusion about model adequacy. |
| f | Understand<br><br>Apply | ***identify and write*** the regression equation.<br><br>***use the regression equation*** for the given problem. |
| g | Analyze<br><br>Evaluate | ***relate and judge*** statistical information from *Question e* and *f*.<br><br>***give reasoning*** according to decision made. |

Meanwhile, Table 4 shows the example of applications of the three instructional domains based on DelMas (2002b). We applied the domains to assess statistical literacy, reasoning and thinking.

Table 5: Mapping the three instructional domains based on DelMas (2002b)

| Question | Domain | Keywords |
|---|---|---|
| a | SL | ***identify and rephrase*** to correct statement. |
| b | SL | carry out simple ***computations***. |
| c | SL,SR, ST | Using statistical information, students should reflect their ***understanding*** about relationship between variables and ***how to construct scatter plot***. |
| d | SL,SR, ST | ***evaluate result*** from the hypothesis procedures |
| e | SL,SR, ST | ***evaluate model adequacy*** based on given statistical information and results from hypothesis test. |
| f | SL | carry out simple ***computations.*** |
| g | SL,SR | use suitable information ***to make decision*** and ***justify reasoning***. |

**Data Analysis**

The students' score for each of the questions were compared. Their SL, SR and ST abilities were compared throughout engineering background. In addition, Question 5 tested focused on procedures and computations and used to identify the gap between computational abilities and SL, SR and ST abilities.

**Results**

Table 6 shows the descriptive statistics. Question 1 gives the lowest average scores. On the other hand, Question 5 is the highest average score.

Table 6: Descriptive statistics for each question

| Descriptive Statistics | Q1 | Q2 | Q3 | Q4 | Q5 |
|---|---|---|---|---|---|
| Average | 3.518 | 5.358 | 5.213 | 4.874 | 6.394 |
| Standard Deviation | 0.758 | 0.717 | 0.647 | 0.682 | 0.576 |

Table 7 shows the heat map for all eighteen engineering program (RK). The results showed that students' were not able to apply simple linear regression concepts tested in Question 1. On the other hand, they performed well in Question 5. This is clearly due to computation based assessment items. In contrast, Question 1 requires understanding about the concepts before students were able to determine the solution. In addition, there are sub-questions in Question 1 which require them to analyze statistical information before they would able to make justification. Therefore, based on the scores, it shows the inability of students to use statistical knowledge (SL, SR and ST) and apply to new situation.

Table 7: Heat map for each final examination questions

| Engineering Programme | Q1 CO3 10% | Q2 C03 10% | Q3 CO3 10% | Q4 CO2 10% | Q5 CO4 10% |
|---|---|---|---|---|---|
| RK01 | | | | | |
| RK05 | | | | | |
| RK07 | | | | | |
| RK08 | | | | | |
| RK12 | | | | | |
| RK13 | | | | | |
| RK23 | | | | | |
| RK24 | | | | | |
| RK28 | | | | | |
| RK32 | | | | | |
| RK45 | | | | | |
| RK56 | | | | | |
| RK84 | | | | | |
| RK85 | | | | | |
| RK86 | | | | | |
| RK89 | | | | | |

| Engineering | | | | | |
|---|---|---|---|---|---|
| RK90 | | | | | |
| RK96 | | | | | |

Minimum                                    Maximum

Table 8: Heat map to compare between engineering programs

| Engineering Programme | Q1 CO3 10% | Q2 C03 10% | Q3 CO3 10% | Q4 CO2 10% | Q5 CO4 10% |
|---|---|---|---|---|---|
| RK01 | | | | | |
| RK05 | | | | | |
| RK07 | | | | | |
| RK08 | | | | | |
| RK12 | | | | | |
| RK13 | | | | | |
| RK23 | | | | | |
| RK24 | | | | | |
| RK28 | | | | | |
| RK32 | | | | | |
| RK45 | | | | | |
| RK56 | | | | | |
| RK84 | | | | | |
| RK85 | | | | | |
| RK86 | | | | | |
| RK89 | | | | | |
| RK90 | | | | | |
| RK96 | | | | | |

Minimum                                    Maximum
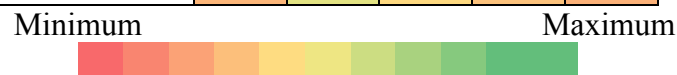
We use the heat map to compare performance between the engineering programs. Based on Table 8, RK28 (Bioprocess Engineering) was the top performer. Meanwhile RK45 (Electrical Industries Engineering) and RK84 (Product Design Engineering) were the bottom two. The performance based on engineering programs could be affected by their academic background and qualifications.

**Discussion: Challenges and New Direction**

The primary goal in statistics education is to enable students to produce reasoned descriptions, judgments, inferences and opinions about data (Garfield, 1998). (Garfield & Ben-zvi, 2005) suggest that several assessing reasoning using variability. Therefore, it can be applied through identifying patterns of variability in a regression model. For this purpose, we use comparative thinking to observe the patterns of variability from two different data sets (regression outputs). This allows students to identify; compare, explain, evaluate and make connections between the outputs. Such process of thinking requires them to think and reason statistically.

However, based on the examination scores, the low achievement from higher order thinking questions and inability to linking concept to context were identified. Therefore, an action research should be conducted by the instructors to design classroom practices with appropriate instructional strategies to support SR and ST. It is clear that students need to be supported with thinking routine activities and appropriate thinking tools while in the statistics classroom. In addition, students' process of reasoning and thinking skillful should be visible. It allows instructors to plan and create culture of thinking classroom environment and innovative approaches for achieving the course learning outcomes to guide students' metacognitive process.

The thinking routine activities and making thinking visible technique were implemented throughout SEMESTER II 2017/2018. This was our first step to inculcate culture of thinking classroom. With the initiatives and continuous monitoring, we hope that the new learning approach helps to enrich students experience in learning statistics, developing statistical competency, SL, SR, and ST skills. However, there are few limitations identified. The following are the new challenges need to be further explored:

1. Students' and instructors' should aware of the crucial needs to innovate from traditional classroom to culture of thinking classroom environment
2. The traditional teaching (teacher-centered) approach need to be replaced to student-centered and active learning to support development of SL, SR, and ST.
3. Encouragement from the management. The management and instructor should show that their value thinking and SL, SR, and ST as the learning outcomes of statistics course over computation or procedures focus in classroom environment and assessment.
4. A well-structured teaching plan, approach, technique and tools are necessary for the instructor to bring appropriate statistics content to the thinking routine activities that support development of SL, SR, and ST.
5. The examination oriented system shape students attitude towards learning. Thinking routine activities were not successful due to the long-term educational training which focused on memorization and computation. Some of the group activities were not actively involved by the group members and failed to reflect their understanding of content, reasoning and thinking skills.
6. To assess SR and ST, the questions constructed minimize computations and focused more on students' ability to use statistical information provided. This type of questions was found with lowest average marks.

Therefore, we believed more action research projects need to be carefully designed to determine the best model of instructional practices in developing SL, SR and ST. Few directions of the research study were identified:

1. Game-based learning to support understanding of statistical concepts.
2. Blended-learning approach can be implemented so that the more time in the classroom can be allocated to the process of skillful thinking within statistics learning outcomes-making students' thinking visible should be encourage and valued, allow thinking time and peer to peer learning, use questioning strategy to deepen understanding, major focus is students' the learning process not for learning for examination purpose.

3. Statistics instructors should work together to plan and reflect upon the outcomes or feedbacks obtain from the action research projects. It is part of instructor professional development.

**Conclusion**

Statistics course has been and will be continuously benefited to engineering students. While many of statistics education literatures are increasingly put into efforts to defined and suggest ways to develop SL, SR and ST, implementing the three domains in our higher education institution is a challenging task. In this paper, we presented our experience in the implementation of SL, SR and ST in statistics classroom. Apart from students' readiness and awareness to move from traditional setting of teacher-centered classroom and learning statistics as they learnt mathematics, these obstacles may need extra focus and work from the instructors to innovate statistics classroom. University management must promote innovation and acknowledge instructors who are willing to give effort, time and energy to enrich students' learning experience.

It is an important remark that promoting culture of thinking within statistics classroom is impossible when instructors act as the source of information. The role of instructor has changed from that of "source of information" to "facilitator of learning" (Garfield 1993). In addition, instructor motivation and understanding the 'why' behind SL, SR and ST skills is essential before any thinking routines activities are implemented. Other theory of learning for example constructivist learning approach can be adopted for developing SL, SR and ST skills.

We adopt the revised Bloom's taxonomy as the foundation to statistics assessment and the taxonomy is also in accordance to Outcome Based Education implemented here in our institution, UniMAP. However, putting revised Bloom's in the context of statistics content and outcomes would not be directly implemented. This is our challenge and currently continuous projects are being monitored to integrate the taxonomy within statistics content and pedagogy. By using revised Bloom's taxonomy and three instructional statistical cognitive domains (literacy, reasoning and thinking), we hope that it could be used as basic framework to guide instructional designs. In addition, the current educational technology advancement through learning management system such as Moodle or UniMAP e-learning will be an advantage for instructors to determine other factors that may affect students' cognitive and behaviorism towards statistical reasoning and thinking. This is our next research direction, to explore the most effective instructional techniques and to develop models of how students shape their statistical understanding.

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**References**

Anderson, L. & Krathwohl, D. A. (2001). *Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Longman.

Ben-Zvi, D. & Garfield, J. (2015). The Challenge of Developing Statistical Literacy, Reasoning, and Thinking. *PhD Proposal*, *1*(August), 1–423. https://doi.org/10.1017/CBO9781107415324.004.

Ben-Zvi, D., & Garfield, J. (2005). Statistical literacy, reasoning, and thinking: Goals, definitions, and challenges. In *The Challenge of Developing Statistical Literacy, Reasoning and Thinking* (pp. 3–15). https://doi.org/10.1007/1-4020-2278-6_1.

Chance, B. L. (2002). Components of statistical thinking and implications for instruction and assessment. *Journal of Statistics Education*, *10*, 1–14.

Chance, B. L., & Garfield, J. (2001). New approaches to gathering data on student learning for research in statistics education. *{Proceedings of the 53rd Session of the International Statistical Institute, August 2001}*. Retrieved from http://www.stat.auckland.ac.nz/~iase/publications/4/751.pdf

Chance, B. L., Tintle, N., Cobb, G. W., Rossman, A. J., Roy, S., Swanson, T., & Jill, V. (2015). *Introduction to Statistical Investigations*. John Wiley & Sons.

Cobb, G. (1992). Teaching statistics. *Heeding the call for change: Suggestions for curricular action*, *22, 3-43*.

DelMas, R. C. (2002a). Journal of Statistics Education, V10N3: delMas discussion. *Journal of Statistics Education*. https://doi.org/10.1017/S0305000902255348.

DelMas, R.C. (2002b). Statistical Literacy, Reasoning, and Learning: A Commentary. *Journal of Statistics Education*, *10*(*3*).

English, L. D., & Watson, J. M. (2015). Exploring variation in measurement as a foundation for statistical thinking in the elementary school. *International Journal of STEM Education*, *2*(*1*),*3*.

Finzer, W. (2013). The Data Science Education Dilemma. *Technology Innovations in Statistics Education*, *7*(*2*).

Forehand, M. (2010). Bloom's Taxonomy from Emerging Perspectives on Learning, Teaching and Technology. *International Journal of Educational Management*, *26*(2), *205–222*.

Friedrich, J., Buday, E., & Kerr, D. (2000). Statistical Training in Psychology: A National Survey and Commentary on Undergraduate Programs. *Teaching of Psychology*, *27(4), 248–257*. https://doi.org/10.1207/S15328023TOP2704_02

Friel, S. N., O' Connor, W., & Mamer, J. D. (2006). More Than "Meanmedianmode" and A Bar Graph: What's Needed to have Statistical Conversation? In *Thinking and reasoning with data and chance: Sixty-eighth yearbook* (pp. 117–137). Published by National Council of Teachers of Mathematics.

Gal, I. (2002). Adults Statistical Literacy : Meanings , Components , Responsibilities. *International Statistical Review*, *70(1)*, *1–5*.

Gal, I., & Garfield, J. (1997). Curricular Goals and Assessment Challenges in Statistics Education. *The Assessment Challenge in Statistics Education*, *1997*, *1–13*.

Garfield, J. (1995). How Students Learn Statistics. *International Statistical Review / Revue Internationale de Statistique*, *63(1)*, *25*. https://doi.org/10.2307/1403775

Garfield, J. (1998). The Statistical Reasoning Assessment: Development and Validation of a Research Tool. *Proceedings of the Fifth International Conference on Teaching Statistics*, *781–786*. Retrieved from papers3://publication/uuid/A57287CF-935F-4599-8895-409C9E0EAC6B.

Garfield, J., & Chance, B. (2000). Assessment in statistics education: Issues and challenges. *Mathematical Thinking and Learning*, *2(1-2), 99-125*.

Garfield, J. B. (2002). The Challenge of Developing Statistical Reasoning. *Journal of Statistics Education*, *10*(3).

Garfield, J., & Ben-Zvi, D. (2005). A framework for teaching and assessing reasoning about variability. *Statistics Education Research Journal*, *4*(1), 92–99. Retrieved from http://eric.ed.gov/ERICWebPortal/recordDetail?accno=EJ847408

Garfield, J. , DelMas, R., & Chance, B. (2003). The Web-based ARTIST: Assessment Resource Tools for Improving Statistical Thinking. In *Paper presented at the Annual Meeting of the American Educational Research Association*. Retrieved from papers3://publication/uuid/F567FA34-BCC6-49A2-A6EC-8BC6BC88BFDC

Garfield, J., & Gal, I. (1999). *Teaching and assessing statistical reasoning. Developing mathematical reasoning in grades K-12* (Reston, L). VA: National Council Teachers of Mathematics.

Garfield, J., & Ben-Zvi, D. (2007). How students learn statistics revisited: A current review of research on teaching and learning statistics. *International Statistical Review*, *75(3), 372–396*. https://doi.org/10.1111/j.1751-5823.2007.00029.x.

Garfield, J., & Ben-Zvi, D. (2009). Helping Students Develop Statistical Reasoning: Implementing a Statistical Reasoning Learning Environment. *Teaching Statistics*, *31(3), 72–77*. https://doi.org/10.1111/j.1467-9639.1990.tb00111.x.

Jones, G. A., Langrall, C. W., Thornton, C. A., Mooney, E. S., Wares, A., Jones, M. R., Nisbet, S. (2001). Using students' statistical thinking to inform instruction. *Journal of Mathematical Behavior*, *20*(1), 109–144. https://doi.org/10.1016/S0732-3123(01)00064-5.

McNamara, A. A. (2015). Bridging the Gap Between Tools for Learning and for Doing Statistics. Retrieved from http://www.escholarship.org/uc/item/1mm9303x

Moore, D. S. (1990). Uncertainty. In L. A. Steen (Ed.), *On the shoulders of giants: New approaches to numeracy* (pp. 95–137). Washington, DC: National academy Press.

Moore, D. S. (1997). New pedagogy and new content: The case of statistics. *International statistical review*, *65(2), 123-137*.

Neumann, D. L., Hood, M., & Neumann, M. M. (2013). Using real-life data when teaching statistics: student perceptions of this strategy in an introductory statistics course. *Statistics Education Research Journal, 12(2)*.

Pfannkuch, M., & Wild, C. (2003). Statistical thinking: How can we develop it? In *Proceedings of the 54th International Statistical Institute Conference*. Voorburg, Netherlands: International Statistical Institute. Retrieved from http://iase-web.org/documents/papers/isi54/3235.pdf.

Pfannkuch, M., & Wild, C. (2004). Towards an understanding of statistical thinking. *The Challenge of Developing Statistical Literacy, Reasoning and Thinking*, *17–46*.

Sedlmeier, P. (2000). How to improve statistical thinking: Choose the task representation wisely and learn by doing. *Instructional Science*, *28*(3), *227–262*.

Silver, H. F. (2010). *Compare & Contrast: Teaching Comparative Thinking to Strengthen Student Learning*. Silver Strong and Associates.

Tishkovskaya, S., & Lancaster, G. (2012). Statistical education in the 21st century:a review of challenges, teaching innovations and strategies for reform. *Journal of Statistics Education*, *20*(2), *1–56*.

Wallman, K. K. (1993). In Enhancing Statistical Literacy: Enriching Our Society. J*ournal of the American Statistical Association*, *88(421), 1-8*.