Teaching and learning statistics in college: how learning materials should be designed

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Abstract. The evolving nature of statistics implies that the skill of reading statistical information to be essential for college students. To encourage the skill, learning materials need to be appropriately developed. This article aimed to synthesize the issues and suggestions from the current empirical research in statistics education relevant to designing statistics learning materials for college students. The data were collected from 111 research articles published from the last 15 years, which were related to teaching and learning statistics in college. Cognitive and social cognitive learning perspectives were used in reviewing and synthesizing the research, which may reveal the different concerns for a specific situation. Three key suggestions for designing statistics learning materials for college students were identified: using real-life data; familiar contexts; and interactive materials. The reviews also suggested the urgent need for research focusing on designing learning materials for statistics.

1. Introduction
The concept of lifelong learning in a broader context requires college students to interact with academic texts. Particularly, the fact that statistics is an evolving science that implies the ability to learn through reading to be prominent for college students. For example, when a student teacher intends to conduct educational research in the future, he/she would need to read the information on the current investigative method in the educational research field. In this respect, the ability to learn statistics using any available learning resources is also an essential skill for this student teacher. Moreover, some studies focusing on college statistics courses suggested that reading comprehension is significantly related to achievement [1], as well as motivation and perception of the course [2].

Reading statistics texts, as reading in other content areas, involves the interaction or transaction between a reader and a text situated in a particular context. Particularly, the density of statistical text [3], lexical ambiguity terms and multi-words phrases [4,5] may be problematic for student reading. Graphical displays, as one type of statistical texts, also have specific characteristics which might be difficult to comprehend [6,7].

Considering the obstacles students might face in reading statistical information, suggestions and recommendations are required related to how learning materials for college students should be designed. Moreover, since one of the learning principles in statistics derived by Garfield and Ben-Zvi [8] was that students learn better through their active involvement in constructing their knowledge, it is necessary to provide opportunities for college students to learn statistics through reading textbooks or didactical materials as one kind of active involvements [9,10]. Thus, how learning materials should be designed becomes an issue when reading statistical information is taken as one approach in college
statistics classes. Accordingly, the goal of this article is to explore and synthesize issues and suggestions for designing learning materials for college statistics based on a review of the current empirical literature on college statistics.

2. The goals of learning statistics at college level

There was an increasingly strong call for statistics education to focus more on statistical literacy, reasoning and thinking in the late of 1990s, which arose by the concern that most statistics courses failed to produce statistically educated students [11]. Since then, the reform movement has been noted in statistics education, which was described by Garfield and Ben-Zvi [12] through changes in content (more data and analysis, less probability), pedagogy (fewer lectures, more active learning), and technology (for data analysis and simulation). More specifically, Garfield [13] classified four goals for introductory statistics course: concepts, skills, types of thinking and attitudes.

Statisticians have discussed the concepts should be taught in introductory statistics course started in the 1990s. A list of topics was proposed by Hogg [14] based on a discussion with statisticians, resulted in four levels of prioritized topics for the course. The highest priority emphasized on understanding basic knowledge, following by methods for investigation of second priority, probability and inference in the third priority, and more advanced methods for investigating data involved in the fourth level. In the more recent year, Burrill and Biehler [15] identified seven statistical ideas that seem to be fundamental for understanding and being able to use statistics in the workplace, in personal lives, and as citizens. The seven ideas are data, variation, distribution, representation, association and modeling relations between two variables, probability models for data-generating processes, sampling, and inference.

There have also been six recommendations provided by the college group of the GAISE (Guidelines for Assessment and Instruction in Statistics Education) for teaching the college statistics course [16]. The six recommendations are as follows:

- Emphasize statistical literacy and develop statistical thinking.
- Use real data.
- Stress conceptual understanding rather than mere knowledge of procedures.
- Foster active learning in the classroom.
- Use technology for developing concepts and analyzing data.
- Use assessments to improve and evaluate students’ learning.

The recommendations may be related to the ways a statistics learning material should be designed. For example, the first three and the fifth recommendations may be relevant to how statistical concepts should be addressed in textbooks and how the knowledge and procedures are connected to underlying concepts. The fourth and sixth recommendations might be included as an activity or part in the exercises or homework.

3. Method

This study was a preliminary stage of a study that aimed to design and validate statistics learning materials that emphasize statistical literacy for Indonesian college students. Based on this purpose, the study may be categorized as a developmental study, which is a type of the educational design research [17]. More particularly, since this preliminary study focused on the exploration of issues and suggestions from empirical literature as the basis in the design, it was considered as the first two phases of the design processes: problem and analysis.

In exploring the issues and suggestions related to learning materials for college statistics, research articles published from 2002 to 2017 in various journal articles were searched and synthesized. However, since research focusing on reading to learn statistics texts and designing statistics learning materials has been hardly found in the current literature, the issues were synthesized from the current literature on teaching and learning college statistics. The type of literature reviewed in this article was the research articles, while the topics of the review were limited to how the content of learning
materials should be designed, excluded the exercises and assessments. Using various keyword combinations, which meet the criteria described above, in two electronic search engines (Google Scholar and ERIC database), resulted in 111 journal articles considered relevant to the focus of the review. In this article, however, only several representative articles for each key suggestion were referred. In addition, by considering the recent trend in statistics education research, two learning perspectives were used in synthesizing the issues from those research articles: cognitive and social cognitive perspectives. Learning materials might be regarded as one type of learning tools in the two learning perspectives. From the cognitive perspective, tools are used to facilitate the connection of new information to prior knowledge, while from the social cognitive perspective, learning tools used in teaching need to motivate learning and decrease anxiety.

4. Results and Discussions
There were three key suggestions identified related to the design of learning materials for college statistics: real-life data, familiar contexts, and interactive materials. The three suggestions were elaborated in the followings with regard to the cognitive and social cognitive perspectives.

4.1. Real life data
From the perspective of cognitive learning, using real-world data and application is intended to connect students’ contextual knowledge or prior experience about data set to the statistical concepts as their new knowledge. This is an effective way to organize and structure the new information to tap the students’ prior experiences. For example, a qualitative study conducted by Neumann et al. [18] showed that using real-life data can promote students' engagement, enhance understanding and learning, remembering of concepts and theory. In this study, 38 psychology students were interviewed about how the use of real-life data was related to their engagement and learning. The datasets used in the course were those that have relevance to the psychology and general interest which were collected from public sources or World Wide Web data repositories. Students also reported getting a broader perspective of the relevance of statistics and more interest. Other studies [19,10] also showed that using real-world application exercises during the course may help students apply their statistical knowledge into other different contexts, the ability to which the author referred to as far transfer. This study using quasi-experimental design method which involved psychology student with a variety of ethnicity (Asian, Hispanic, African American and more than half were Caucasian). The materials for real-world exercises were articles from outside the academic environment which require students to summarize and critic the statistical concepts used in the articles.

Social learning theory, on the other hand, views real-world application data as the means to motivate learning, because learning and behavior are affected by students' thoughts and beliefs. Some research in this group assumed that by using real-world application data, students would appreciate the usefulness of course material and beliefs the relevance of statistics to their professions and increase attitudes. Hiedemann and Jones [20] compared two types of approaches in introductory statistics course for business students, i.e., Academic Service Learning (ASL) which require students to work with a real organization to conduct research, and Case Studies (CS) in which the task for students was to imagine themselves as business professionals or statistical consultants charged to make a recommendation or provide information to a client using available data set. Although no difference was found in examination performance, students from ASL group were more likely to agree that statistics have the application to their profession. Wiberg [21], on the other hand, revised statistics course for psychology students by using research problem relevance to psychology throughout the course. The results showed that students performed better and showed positive attitudes in the revised course.

4.2. Familiar contexts
The characteristics of statistical data, which cannot be separated from contexts, make kind of contexts as a factor plausible in student learning. Similar to that of real-life data, the familiar context from the
cognitive perspective serves as the connection of students’ prior experience to the statistical concepts. From the social cognitive perspective, it is suggested as a means for encouraging students’ learning motivations.

The familiar contexts are those relevant to students’ field of study. The studies by Hiedemann and Jones [20] and Wiberg [21] discussed above showed the positive impacts of using contexts that relevant to students’ field of study. Another study by Abdelbasit [22] suggested that unfamiliar contexts might be problematic for non-native English students learning by using textbooks from English speaking country. In addition, these students tended to focus on technical parts when working with problems from the textbook and ignoring the contexts of the problems.

4.3. Interactive materials
Research suggests that students learn better if they are engaged in their learning. In addition to reading to learn the statistical concepts in textbooks [9,10] using interactive, such as simulations or interactive animations [23,24,25] can be regarded as one kind of the active involvement in learning statistics. The interactivity has been acknowledged as one advantageous feature of using technology as a learning tool.

There has been a different trend of using types of technology in teaching statistics, following the more current development of technology. From the cognitive perspective, technology is used to make the information in an organized or structured form. Several studies showed that the interactive (simulation or interactive animation) and dynamic features of technology, visualization, and constructive representations benefit student learning, which allows them to learn the concepts by their own [24], besides its capability to facilitate the numerical and graphical parts.

Social cognitive perspective, on the other hand, assumes that using technology may stimulate attention and making learning more attractive and fun for students. Some studies have shown that, due to the availability of the practice materials with immediate and targeted feedback, the interactive materials made students more willing to work extra beyond the course requirement [26] or spent more time to the course [27].

5. Conclusion
The three key suggestions identified in this study are in line with the recommendations from GAISE [17] for teaching college statistics, although some of the recommendations were not the focused on this review, such as those related to assessments. Numerous empirical studies have suggested using real-life data and familiar contexts in college statistics. Also, the contexts that are relevant to students’ field of study might also be appropriate to use in statistics learning materials, since the familiar contexts might be used as the connection between students’ experiences with statistical concepts and their learning motivation. Furthermore, using interactive materials can be related to the recommendation of using technology from [17]. The interactive materials, which have the dynamic visualization and constructive representations, allowed students to learn statistical concepts on their own. In addition, due to immediate feedback for the practice materials provided in the interactive materials, students may be motivated in learning.

This review also showed the urgent need for further studies focusing on designing learning materials for statistics. Furthermore, when reading to learn is intended in college statistics classes, criteria for measuring the appropriateness of reading materials for the different reading levels of students can be another important issue for future research.

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