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STATISTICS EDUCATION RESEARCH JOURNAL

The *Statistics Education Research Journal* (*SERJ*) is a peer-reviewed electronic journal of the International Association for Statistical Education (IASE) and the International Statistical Institute (ISI). *SERJ* is published twice a year and is open access.

SERJ aims to advance research-based knowledge that can help to improve the teaching, learning, and understanding of statistics or probability at all educational levels and in both formal (classroom-based) and informal (out-of-classroom) contexts. Such research may examine, for example, cognitive, motivational, attitudinal, curricular, teaching-related, technology-related, organizational, or societal factors and processes that are related to the development and understanding of stochastic knowledge. In addition, research may focus on how people use or apply statistical and probabilistic information and ideas, broadly viewed.

The *Journal* encourages the submission of quality papers related to the above goals, such as reports of original research (both quantitative and qualitative), integrative and critical reviews of research literature, analyses of research-based theoretical and methodological models, and other types of papers described in full in the Guidelines for Authors. All papers are reviewed internally by an Associate Editor or Editor and are blind-reviewed by at least two external referees. Contributions in English are recommended. Contributions in French and Spanish will also be considered. A submitted paper must not have been published before or be under consideration for publication elsewhere.

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EDITORIAL

Welcome to the first issue of *SERJ* for 2022. Last year was an exciting year for SERJ. We moved our operation into an Online Journal Submission system and all articles are now being assigned DOIs. Thanks to the hard work of Tim Overhues, all papers published previously in SERJ are being moved in to the new OJS system and assigned DOIs as they are republished to the new site. The archived papers will continue to reside in both their original and new location. Many thanks to Gail Burrill, Daniel Frischemeier, and Noleine Fitzallen for setting up and organizing the SERJ DOI system. Daniel and Noleine also deserve a hearty thanks for their incredible work on the Special Issue of SERJ devoted to research in statistics education in Latin America. They and the guest editors did a fantastic job putting together a superb group of papers and laying the groundwork for SERJ to accept, review, and publish papers in Spanish in the future. As always, many thanks go to Noleine and the SERJ Associate Editors for Regular Papers, without whom this Issue would not have been possible.

This Issue of SERJ has ten articles, but it begins with two Letters to the Editor. The Letters represent a conversation between statistics education researchers around a recently published SERJ article on the analysis of statistics textbooks. As Editor, I am glad to be able to facilitate this type of conversation between researchers as part of the SERJ publication process. In fact, I would not be surprised if the papers from this Issue lead to future Letters to the Editor. The first four regular articles in the issue represent the instrument development and measurement aspect of statistics education research and provide an opportunity for future discussions about general topics in measurement in the field. In the first of the articles, the authors illustrate challenges to the use of the family of instruments named the Survey of Attitudes toward Statistics (SATS). The second and third articles use the SATS instruments to investigate associations between attitudes toward statistics and cognitive emotion regulation strategies, satisfaction of psychological needs, gender, and statistics anxiety, in the first case, and statistical reasoning and anxiety, in the second case. The subsection on measurement in statistics education concludes with a presentation of a new instrument, the COMputational Practices in Undergraduate TEaching of Statistics (COMPUTES) instrument, which measures the extent to which statistics courses incorporate student learning outcomes around computing.

Following the subsection on measurement are two articles on the teaching and learning of statistics in the middle grades. The first of these articles contains a comprehensive theoretical framework to describe learning outcomes associated with statistical literacy and presents a feasibility study indicating a set of design principles for classroom activities that aid middle school students in building statistical literacy. The second reports on the development of student understanding of variability when using the statistical process applied to an engineering setting (catapults). This paper is followed by a paper describing the use of feedback to help prospective primary school teachers pose statistical questions to begin the statistical process with their students. Next is a paper describing the use of Worked Example Videos (WEVs) in Introductory Statistics courses for business majors. The results of the study indicate the use of the WEV technology, with relatively low barriers to entry in internet-enabled locations, improve student persistence and positive attitude toward statistics. The penultimate paper in the issue describes the perspectives about the discipline of statistics held by Graduate Teaching Assistants (GTAs) and the implications for these perspectives on the Professional Development needs and teaching of the GTAs. The final article in the issue describes an exploration of probability literacy of adults and children in Brazil around the context of fair games.

In the first article, Douglas Whitaker, Alana Unfried, and Marjorie Bond explore two types of challenges to the use of the Survey of Attitudes Towards Statistics (SATS) family of instruments: challenges to the interpretations of the scale scores and challenges in using the instruments with populations different from the population of undergraduate students enrolled in an introductory statistics course for which the instrument was designed. While the authors conclude that for many researchers, the use of the SATS family of instruments continues to be suitable, they raise important issues for the field moving forward. In particular, they caution researchers around interpretation of change scores, particularly for the constructs of Difficulty and Effort. Furthermore, they posit that recent findings that question the factor

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structure of the SATS-36 may be due to a misalignment with the Expectancy Value Theory (EVT) on which the SATS-28 was built. Finally, the authors suggest the need for new and updated instruments for use with populations other than undergraduate students in intorductory statistics. These instruments should be designed using current measurement methodology and publications describing the evidence of validity and reliability of the new instruments should align with the current recommendations of the measurement research community.

In the second article, Sara-Emilie McIntee and colleagues studied the relationship between attitudes towards statistics, cognitive emotion regulation strategies, satisfaction of psychological needs, gender, and statistics anxiety, using the SATS as a measure of attitudes. While there are a number of studies that have explored the relationship between some of these variables, this is the first study to explore the relationship between emotion regulation strategies and the satisfaction of basic psychological needs and statistics anxiety. Using a sample of 270 university students from institutions across Canada, the researchers found that four different variables uniquely predicted statistics anxiety. Furthermore, these variables were distinct with little shared variance. When students perceived their statistics classes as more valuable, interesting, achievable, enjoyable, and/or worthy of effort, they were also more likely to experience lower levels of statistics anxiety. The study found that maladaptive strategies were associated with higher levels of statistics anxiety, whereas adaptive strategies may not be associated with levels of statistics anxiety. Although there appeared to be no indirect moderation effect of satisfaction of psychological needs on statistics anxiety, the results indicated a potential direct effect of satisfaction of psychological needs, whereby students whose psychological needs were not fulfilled were more likely to experience statistics anxiety. Finally, women were more likely than men to report statistics anxiety. The study suggests potential ways of reducing statistics anxiety of students studying in social sciences: discussing with the students the utility of statistics for their future career and how to avoid maladaptive regulation strategies as students of statistics, as well as helping students to approach statistics activities as occasions to foster their feelings of autonomy, competence, and social support. The authors suggest that future work on the relative importance of each factor will help to better understand statistics anxiety and means to reduce it.

Siti Shahirah Saidi and Nyet Moi Siew explored the relationship between statistical reasoning, attitudes toward statistics, and statistics anxiety of grade 10 science students in Sabah, Malaysia. With a sample of 320 students and using the Survey of Attitudes Towards Statistics (SATS) in addition to the Statistical Reasoning Test Survey (SRTS), and the Statistical Anxiety Scale (SAS), the authors found a positive relationship between attitudes toward statistics and statistical reasoning and a negative relationship between statistics anxiety and statistical reasoning. The subjects exhibited a positive attitude toward statistics with a moderate level of statistics anxiety. The authors note the students in their study were relatively proficient in the computational and procedural aspects of statistics but struggled when asked for justifications and reasoning. They suggest that instructors of statistics at the secondary level provide more direct instruction or classroom activities to help students develop statistical reasoning skills.

Chelsey Legacy, Andrew Zieffler, Elizabeth Brondos Fry, and Laura Le introduce the SERJ readers to the COMputational Practices in Undergraduate TEaching of Statistics (COMPUTES) instrument, designed to measure the extent to which computation practices are included in university level introductory statistics courses. The theoretical framework underlying the development of the COMPUTES instrument contained 4 categories, of which the COMPUTES addresses three: data practices, modeling/simulation practices, and computational problem-solving practices. The article provides validity and reliability evidence for the COMPUTES instrument. Based on the fit indices, responses to the COMPUTES items are multidimensional, albeit correlated, in nature. The correlation structure among the latent factors suggests that instructors' emphases on data practices and coding practices are highly related, while emphasis on simulation practices are less related to the two other domains. An investigation into differences in response patterns for instructors at different types of institutions generated a number of hypotheses that warrant further investigation. For example, a bimodality of scores in the Coding Practices domain points toward a potential dichotomy across instructional settings. Future work, using qualitative or mixed methods, could explore why instructors choose to include or not include certain computational practices in their instruction and might uncover the computational practices that are most beneficial to student learning in statistics and

data science. In addition, the fact that the item thresholds were almost all above zero suggests the instrument would benefit from additional items that measure differences at the lower end of the constructs.

Christian Buscher reports the results of a Design Research centered on the development of didactic materials for developing statistical literacy of middle school students. This paper extends previous work in statistics education research through two contributions: elaborating a specification of the learning content of statistical literacy and by identifying design principles for developing statistical literacy in middle schools that are transferable to many different school contexts. The author begins the paper by providing a theoretical model specifying learning outcomes for statistical literacy. The model likens the data-producing side of statistical literacy to selective reading, during which phenomena are transformed into data, data into models, and models into statistical arguments: a process through which the message is clarified, although at the cost of information loss. Due to the information loss, a consumer of statistics must use imaginative reading: hypothesizing about the model behind the statistical argument, about the data behind the model, and about the phenomenon behind the data. The activities of selective and imaginative reading, namely encoding and decoding, de-abstracting, and de-interpreting thus provide a specification of the learning content of statistical literacy. The Design Research study based on the framework identified four design principles that support the development of statistical literacy in middle school students: resolving conflicting information, incomplete information, critical contexts, and digital tools. The results of the study indicate the feasibility of the identified design principles and the statistics education community will benefit from further findings of similar research as the design principles could be applicable to a wide variety of classrooms supporting acquisition of statistical literacy for many of the world's future adult citizens.

In an article dedicated to their colleague, Suzie Wright, authors Jane Watson, Noleine Fitzallen, and Ben Kelly describe the implementation of an activities designed to help students build their understanding of variability while learning about the science of force in the engineering context of designing catapults. Readers familiar with the Next Generation Science Standards (NGSS) in the United States may see the connections between the catapults activity described in this article and the Three Dimensional Learning framework associated with the NGSS. The authors explored how students understanding of variation during a STEM inquiry can be categorized using the Structure of Observed Learning Outcomes (SOLO) framework overlayed on a problem-solving pathways framework. Student work from 50 grade 4 (aged 9–10) students in two different classes was analyzed. The researchers found students worked in the Ikonic (IK) and Concrete Symbolic (CS) modes, but also found evidence of multimodal responses, indicating a blending of IK and CS modes. The authors not only illustrate the value of the activity in developing student thinking about variability and the use of the SOLO model on the characterization of student learning in statistics, they also posit the value of the SOLO model on student learning in the sciences. Given the connections of the activity to best practices for school-level teaching in science, engineering, and statistics (the activity is aligned with the GAISE K-12 guidelines), this article has the potential to inform a wide STEM education audience.

Aisling Leavy and Daniel Frischemeier address the first step of the process of statistical inquiry (the PPDAC) cycle: asking or posing statistical questions. Best practices for statistics education reminds instructors to provide students opportunities to work within the cycle of statistical inquiry, which requires the posing of good statistics questions to begin the inquiry. In this paper, the authors explore the use of feedback to help prospective elementary school teachers write and recognize good statistical questions. While many of the 158 prospective teachers could write meaningful and interesting questions at the outset of the study, they struggled to define variables clearly, incorporate more than one variable, and support a global view of data. While peer-feedback did not produce large changes in the quality of the questions posed, after feedback from the instructor, the prospective teachers wrote more multivariate questions with a clearer description of the variables incorporating a global view. As statistics becomes a more prominent feature in primary school curricula and more prospective primary school teachers need background in the PPDAC cycle, the results of this study provide directions for future research as well as recommendation for prospective teacher development.

Sarah Dart explores the use of worked example videos (WEVs) in introductory business statistics courses at the university level. WEVs provide step-by-step solutions to exemplar problems and are loaded

into a course management system where students can watch and rewatch them at their convenience. Based on the self-regulated learning theory and the cognitive theory of multimedia learning, WEVs have high potential for improving student learning and attitudes in statistics, which has been confirmed through empirical studies in other disciplines. Using complete cohorts of students at one university over a three-year period, the author found high usage of WEVs, particularly immediately prior to a summative assessment. In addition, more students persisted in their statistics courses and fewer than expected failed after WEVs were put into widespread use. Interviews with a subset of students who used WEVs indicated that students appreciated the ability to watch and rewatch videos, to rewind and replay segments, and to use videos for one problem when solving a similar problem. Finally, course evaluations indicated an increase in student satisfaction for students in the WEV cohorts. Given the low barrier for entry into this technology in locations that have widespread use of an LMS, these results may encourage other instructors to create WEVs as part of a course package.

Kelly Findley used a longitudinal, multi-case design to explore the disciplinary perspective of first year graduate students in statistics working as Graduate Teaching Assistants (GTAs) in a university Statistics Department in the United States. As first-year graduate students, the participants were still developing their own notions of the discipline of statistics. Meanwhile, as GTAs, these same subjects were charged with transmitting the discipline to undergraduate (tertiary) students from across many disciplines. The results of the study include explanations of the disciplinary perspectives of the participants as well as tensions between these perspectives and the subjects' pedagogical views on teaching undergraduate introductory statistics courses. The results in the paper add to the small, but growing body of research on the training of statistics GTAs. In addition, the author provides explicit recommendations for departmental training of statistics graduate students serving in the dual role of graduate student and graduate instructor. Given the rise in enrolment and undergraduate statistics courses and subsequent increase in the use of GTAs to teach these courses, the recommendations of this paper are timely and can serve to improve the teaching of statistics at the tertiary level.

In the final paper of the issue, Rita Batista, Rute Borba, and Ana Henriques compare probabilistic reasoning of children and adults when assessing fairness of games of chance. The 15 Brazilian children and 15 Brazilian adults all had similar background in probability education. The authors found that judgements made about the fairness or unfairness of games depended on the subjects' understanding of randomness and sample space and their ability to compare probabilities. Moreover, the results from the adult subjects did not differ from those of the children, although the adults did provide more non-mathematical arguments in their responses. Among the interesting findings of the study, the authors concluded that it was easier for the subjects to identify unfair games as unfair than to identify fair games as fair. They attribute this finding to the confusion of the subjects between fair meaning each player has the same probability of winning, which may be any value from 0 to 1, and equiprobable outcomes of the game trial, i.e. that any or all players have a 50% chance of winning on any particular play of the game. The authors conclude with a recommendation that fairness be addressed explicitly in probability instruction and suggest the games presented in the paper could be used as the basis for such instruction.

I hope the SERJ readers enjoy this set of papers and many thanks again to the SERJ Assistant Editor, Associate Editors, Reviewers, and Authors, without whom this Issue would not exist.

JENNIFER J. KAPLAN
Editor