SUPPORT AND CONSIDERATIONS FOR IMPLEMENTING THE SURVEY TOOLKIT PROJECT-BASED CURRICULUM USING TINKERPLOTS®

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ABSTRACT: The Survey Toolkit (Walsh, 2009) curriculum, including use of TinkerPlots® technology tools, was developed based on a review of the research providing guidance in best practices and methodology in teaching survey research to elementary and middle school students. The paper presents the literature review beginning with the development and support of statistics education and it importance for informing and decision-making, especially relevant today due to social media influences in persuading public opinion and trafficking of fake news. The review discusses implementation concerns and pedagogy issues in delivery of a statistics curriculum. Discussion of research directions with consideration of The Survey Toolkit curriculum using TinkerPlots® as a potential curriculum for authentic student data generated project learning is presented.

Keywords: TheSurveyToolkit curriculum, integrating TinkerPlots®, elementary/middle schoolstatistics, authenic/stochastic/learning; staff development pedagogy

INTRODUCTION

The Survey Toolkit Collecting Information, Analyzing Data and Writing Reports (Walsh, 2009) curriculum was written to provide a methodology for upper elementary and middle school students to develop a survey research projects. The curriculum is integrated with the *TinkerPlots*® software program allowing for visual data analysis using graphing to develop statitical conceptual thinking (e.g., ideas about variablility and measures of center), describe data plots, and make inferences beyond the data. The curriculum includes *The Survey Toolkit Resource Manual* (Walsh, 2010) written to support *The Survey Toolkit* text providing additional support in developing survey questionnaires, presenting a notetaking strategy for writing a research report, selecting a sample, and providing teaching resource appendix activities.

During development of *The Survey Toolkit* curriculum a review of the literature was conducted to provide guidance and information about best practices to support teachers in implementating a statistics research project for students to learn effectively. More recently research on teaching survey and data analysis was studied to review current information and trends in this curriculum area supporting authentic student project work in learning statistics, particularily focusing on the use and integration of technology programs like *TinkerPlots*®.

The specific topics of the review will be examined in the paper and include historical development and support for teaching statistics, national guidelines and projects for developing a statistics curriculum, appropriate student statistics curriculum content and learning skills, student conceptions in developing statistical literacy, use of technology tools like *TinkerPlots*®, and teacher implementation considerations of a data analysis curriculum. A final discussion about the implications of the review of the literature related to use of *The Survey Toolkit* curriculum and need for further research is also presented.

Historical Development in Statistics Education

The study of statistics and probability is historically rooted, and more recently in the 20th century statistics began to emerge out of other disciplines. Shaughnessy (1992) reports that statistics and probability appears to have been an integral part of the mathematics curriculum in many European countries for some time dating back to the 17th century. Hacking (2006) review of past events reports the decade around 1660 was the birth time of probability. According to Hacking, in 1657 Huygens wrote the first probability textbook that was first to mention numerical measurements and included aleatory problems.

In *the Taming of Chance* Hacking (1990) argues that during the nineteenth century the erosion of the idea of determinism (i.e., the past does not determine what will happen next) was being replaced by the laws of nature or the enumeration of people and their habits. According to Hacking, society became statistical and most of the law-like regularities were first perceived in connection with deviancy (e.g. crime, disease, and madness) with government information based on statistical inference to improve and control a deviant subpopulation by classification. Hacking elaborates on society early use of statistics during this period, based on collection of data about people, including first attempts to use medical statistics as evidence for the efficacy of rates of cure and use of crime statistics for designing the most efficient jury system.

Garfield and Ben-Zvi (2007) discuss the development of the field of statistics education during the 20th century leading to more recent support from National Council of Teacher of Mathematics (NCTM) and other organizations. Figure 1 shows a summary of these authors research highlighting development and evolution of this separate discipline to provide understanding and insight for teaching today. More recent pedagogy and content focused on technology use for introductory statistics instruction using graphing calculators, with graphic simulations using multimedia (Moore, 1997). Garfield and Ben-Zvi, also highlight *Technology Innovations in Statistics Education* report on studies using technology to improve statistics learning at all levels from kindergarten to graduate school and professional development.

English and Watson (2015) report that since the introduction of statistics into the school mathematics curriculum (e.g., Australian Education Council 1991) there has been a growing awareness of the inadeuacy of focusing solely on the teaching of procedural skills in calculating statistics without adequate attention given to teaching informal inference, especially at the elementary level. Informal inference is the process of using the evidence provided by data to answer questions and write conclusions about variability beyond the data. Examination of the literature more recently provides support in teaching informal inference at the upper elementary and middle school level (Watson & Moritz, 1999; Ben-Zvi, 2006; Watson, 2008; Paparistodemou & Meletiou-Mavrotheris, 2008; Watson & Donne, 2009; Makar, 2013; Makar, 2015; Ben-Zvi, Bakker & Makar, 2015) along with activities used successfully with students to develop awareness of variation, at the heart of statistical reasoning. The use of technology programs, like *TinkerPlots*®, used in conjunction with curriculum supporting the learning of informal inference would need to be added to update the timeline shown below.

Figure 1. The Historical Development of the Field of Statistics Education

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1944 – American Statistical Association (ASA) develops the section on training of statisticians that later became the Section on Statistical Education in 1973.
1948 – The International Statistical Institute (ISI) forms an education committee focusing on training statisticians, and later broadened to include training or education at all levels.
1967 – A joint committee is formed between ASA and NCTM on curriculum in statistics and probability for grades K-12.
1970's (early) – Instructional materials begin development to present statistical ideas.
1970's (late) – ISI creates a task force on expanding the teaching of statistics in the K-12 curriculum reporting the lack of coordinated efforts, appropriate instructional materials, and adequate teacher training.
1980's – Conferences on teaching statistics emerge including the first International Conference on Teaching Statistics (ICOTS) held in 1986 and has continued every four years.
1990's (early) – George Cobb and a working group produce guidelines for teaching statistics at the college level, referred to as the new guidelines for teaching introductory statistics.
1990's (late) – Increasingly strong call for statistics education to focus more on statistical literacy, reasoning, and thinking. Moore (1997) recommends changes in content pedagogy using active learning and technology for data analysis and simulations.
1999 – The International Research Forums on Statistical Reasoning, Thinking and Literacy (SRTL) begins research studies examining statistical literacy, reasoning and thinking leading to developing learning goals for students at all levels.
2005 – The American Statistical Association endorses two reports for statistics education at the Pre-K to 12, and the other focused on introductory college courses (The GAISE project).
Today – Teaching statistics with technology tools, like *TinkerPlots*®, to represent data and make informal inferences.

Support and Need for Statistics Learning

The widespread use of statistics in our life today has become even more paramount in the 21st century. The ability to collect, organize, describe, display, and interpret data, as well as making decisions and predictions on the basis of that information, are skills that are increasingly important in a society based on technology and communication. Statistics and the use of probability data to help make decisions in business, government, research and everyday life is of uppermost significance. Statistics has become an important tool in the work of many academic disciplines such as medicine, psychology, education, sociology, engineering and physics, just to name a few (Hung 1999).

The study of statistics provides students with the tools and ideas to use in order to react intelligently to quantitative information in the world around them (Garfield & Ben-Zvi, 2007). The NCTM Standards (2000) report the use of statistics in everyday life is staggering and is found in consumer surveys that guide the development and marketing of products, polls helping to determine political-campaign strategies, and experiments used to evaluate the safety and efficacy of new medical treatments. The NCTM report also says statistics are misused to sway public opinion on issues or to misrepresent the quality and effectiveness of commercial products. NCTM believes that students need to understand probability and statistics to become informed citizens and intelligent consumers.

Greer (2000) expresses the importance of statistical education influenced by technological developments as the ratio:

$$\frac{\text{access to data}}{\text{analytical and critical tools for interpretation}}$$

is accelerating out of control. Greer reports most of the statistical information to which the general public is exposed is presented by people with a vested interest to persuade.

Providing students with a methodology for collecting information and facts from multiple sources for conducting research projects and developing survey questionnaires is needed more than ever. This is particularly true in an era where social media traffics fake news websites that publish hoaxes, propaganda, and misinformation (e.g., research findings) readers believe to be true. These fake news sites, over 50 listed on Wikipedia (Wikipedia, 2017), along with use of "clickbait" web content publishing sensationalist headlines or click-thoughts over online social networks influences political views and orientation of personal values.

National Guidelines and Projects for Developing a Statistics Curriculum

Given the development and evolution of the statistics movement toward literacy at all levels, and current widespread use of statistics in society, support for providing a statistics curriculum in schools has been documented. Garfield and Ben-Zvi (2007) report a need to improve students' ability to think statistically with statistical reasoning becoming part of the mainstream school curriculum in many countries. *A National Statement on Mathematics for Australian Schools* (Australian Educational Council, 1991) and *Mathematics in the New Zealand Curriculum* calls for considerable statistics to be taught as part of school mathematics programs, in part to empower students to critically evaluate data and claims made about data.

National calls for increased attention to statistics have been documented providing guidelines for curriculum development. The National Council of Teacher of Mathematics (NCTM, 2000) Data Analysis and Probability Standards report recommends that instructional programs for all students include these three areas related to data and statistical methods, and include the following grade six to eight expectations (refer to Figure 2).

Figure 2. NCTM Data Analysis and Probability Standard for Grades 6-8

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1. **Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them**
    - Formulate questions, design studies, and collect data about a characteristic shared by two populations or different characteristics within one population;
    - Select, create, and use appropriate graphical representations of data, including histograms, box plots, and scatterplots.
2. **Select and use appropriate statistical methods to analyze data**
    - Find, use, and interpret measures of center and spread, including mean and interquartile range;
    - Discuss and understand the correspondence between data sets and their graphical representations, especially histograms, stem-and-leaf plots, box plots, and scatterplots.
3. **Develop and evaluate inferences and predictions that are based on data**
    - Use observations about differences between two or more samples to make conjectures about the populations from which the samples were taken;
    - Make conjectures about possible relationships between two characteristics of a sample on the basis of scatterplots of the data and approximate lines of fit;
    - Use conjectures to formulate new questions and plan new studies to answer them.

(NCTM, Data Analysis and Probability Standard for Grades 6-8, 2000).

The report supports work in data analysis and probability in offering a natural way for students to connect mathematics with other school subjects and with everyday experiences. Similar expectations have been supported by Rutherford and Ahlgren (1990), in the American Association for the Advancement of Science's (AAAS). These authors describe statistics mathematics as a thinking process including the teaching of summarizing data using mean; use of samples and size; and the use of logical reasoning to check the validity of hypotheses for producing conclusions.

The American Statistical Association (ASA) in conjunction with NCTM have supported for years to infuse more exploratory data analysis and elementary statistics into the school curricula. This effort has resulted in the Quantitative Literacy Project (QLP), which included data analysis activities designed for students to interpret real data sets (e.g., tables and graphs) and then create line plots, stem-and-leaf plots, box plots, scatter plots, and calculate or show basic statistics (i.e., median, mean, quartiles and outliers) (Landwehr & Watkins, 1986). These authors report that QLP de-emphasizes use of algebraic formulas for analyzing data. Also included during this reform period has been the Reasoning Under Uncertainty curriculum emphasizing learning by doing, using an interactive graphic software to give students experience with fundamental concepts (Rubin and Rosemary, 1990). The Activity Based Statistics Project focuses on data driven activities using graphic displays (Scheaffer, R., Watkins, A., Witmer, J., & Gnanadesikan, M., 2004).

In the GAISE project (Franklin & Garfield, 2006) report detailed guidelines for developing important ideas of statistics for the pre- to college curriculum, complementing the NCTM standards. These authors describe desired learning goals to help students develop literacy and the ability to think statistically in an introductory course recommending emphasis on developing statistical thinking; using real data; stressing conceptual understanding; promoting active learning; using technology to analyze data; and assessments to improve student learning.

The national calls, organizational support, and project developments have increased attention for statistics instruction, and the need for appropriate curricula for students and teachers. In order to develop a curriculum focused on use of real student data in an active learning context, integrated with technology, it is necessary to examine goals and specific learning skills that will promote statistics literacy.

Student Content Knowledge and Skills for a Statistics Curriculum

To begin examining elements for statistical literacy it is necessary to identify broad goals and reasoning skills students need to acquire as part of an effective curriculum. Next, some specific learning skills and topics that are important for developing student understanding of statistics will be reviewed.

Gal and Garfield (1997) examine the concepts and procedures that are important for students to learn statistics. The authors outline several goals for statistics instruction and these are summarized in Figure 3.

Figure 3. Goals for Statistics Instruction by Gal and Garfield (1997)

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1. **Understand the Purpose and Logic of Statistical Investigations.** As students carry out statistical investigations they need to study and understand the logic behind sampling populations, the notion of error in measurement and inference, and the need to find ways to estimate and control errors.
2. **Understand the Process of Statistical Investigation.** Designing a plan for data collection becoming familiar with the specific phases of statistical inquiry including; formulating a question; planning a study; collecting, organizing and analyzing data; interpreting findings; discussing conclusions and implications from the findings; and evaluating issues for further study.
3. **Master Procedural Skills.** Mastering statistical investigation skills involving organizing data; computing needed indices (e.g., median, average, and confidence interval); and construct and display useful tables, graphs, plots, and charts, manually or assisted by technology.
4. **Understand Mathematical Relationships.** Developing intuitive and formal understanding of statistical displays (e.g., graphs), procedures and concepts. For example, explain how the mean is influenced by extreme values in a data set.
5. **Develop Interpretive Skills and Statistical Literacy.** Students need to interpret results and develop awareness of possible biases or limitations on the generalizations that can be drawn from data used in statistical investigations. Learning how to interpret results to pose critical and reflective questions about the data findings is needed.
6. **Develop Ability to Communicate Statistically.** Communicating effectively using appropriate terminology to present results of statistical investigations. Students also need to convey results in a

convincing way, construct reasonable arguments based on data or observations, and develop skills to be able to challenge the validity of other people's statistical investigations or generalizations made on the basis of a single study of a small sample.

These authors report these broad goals help students develop statistical reasoning skills in an information-laden society. They also believe it is helpful to delineate some specific types of reasoning students need to develop as they learn statistics in the elementary and secondary school. These specific types of statistical reasoning are summarized as follows:

1. **Reasoning about data:** Knowing how the type of data (e.g., quantitative or qualitative) leads to a particular type of table, graph or statistical measure.
2. **Reasoning about representations of data:** Understanding how to read and interpret graphs; modify graphs; and recognize shape, center and spread.
3. **Reasoning about statistical measures:** Knowing predictions for large samples will be more accurate than for small samples; and understanding measures of center, spread and position about a data set.
4. **Reasoning with samples:** Understanding how samples are related to populations and what can be inferred from a sample or cautious when making inferences made on small or biased samples.
5. **Reasoning about association:** Knowing how to judge and interpret a relationship between two variables and that a strong correlation between two variables does not mean that one causes the other.

Gal and Garfield provide these guidelines for instruction in statistics education, along with the types of statistical reasoning needed for students to learn.

Chance and Rossman (2001) discuss some general propositions and topics students should learn in statistics. According to these authors, students need to know how to formulate a question before collecting data. Chance and Rossman report that by starting with the question and deciding what data will best address it, students learn the tools and good habits of statistical thinking in a logical order. Ideas of data collection should also be taught at the early stage to include concepts of bias, precision, representative samples, and legitimacy of conclusions. These authors also suggest the following topics should emerge including data production issues with regard to measurement, sampling and experimentation; introducing and revisiting fundamental ideas (i.e., variability, relationships between variables, and reasoning of inference); emphasizing common elements of analysis that arise in different situations (e.g., progress from graphical displays to numerical summaries); providing technology and simulations; and understanding sampling distributions as crucial for understanding concepts of inference.

Broad goals, reasoning skills, general propositions, and topics needing emphasis for an effective statistical literacy program for students have been presented. Support and direction for teaching statistics suggests one way to help students value statistics may be to embed statistics within other disciplines (Garfield & Ahlgren, 1988; Rutherford & Ahlgren, 1990). Greer (2000) reports as statistics has entered school curricula in countries across the world, it has been primarily located within mathematics, with considerable debate as to whether statistics is part of mathematics or considered a liberal art. Identifying appropriate learning skills and topics for an integrated statistics curriculum provides a foundation for curriculum developers, however, it is necessary to also examine common student misconceptions in statistical understanding to target areas for providing teacher scaffolding and support.

Student Statistical Thinking and Learning

Student learning issues and conceptions in achieving statistical literacy is documented in the literature. Awareness of these issues is important for the teacher in order to know when to provide instructional scaffolding to change students' beliefs and intuitions about statistical phenomena. Awareness of student thinking about samples, aggregate data, graph analysis, distributional reasoning from the population, variability, measures of center, fair testing, and other statistical ideas will improve the development and implementation of an effective statistics curriculum. Intervention strategies are emerging in the literature to support student conceptual development of statistical concepts along with developing conclusions based on inferences drawn from the data. Variation is a foundation of statistics providing the basis from which inferences can be drawn during statistical decision making (Watson & Wright, 2008). Much of the more recent research supports the use of technology, like *TinkerPlots®*, to assist students in interpreting their graphed "data plots" and to draw inferences. Makar (2013) describes inferring as follows:

> Informal statistical inference uses data to make predictions or conclusion about an uncertain event. An inference must be stated with uncertainty because the exact answer is not known for sure, but can only be estimated. (Makar, 35, 2013).

Makar reports describing data and inferring beyond data are at the core of statistics. In this section of the paper discussion of statistical conceptual thinking of students and inference will be presented along with emerging strategies to support learning.

Graphing Skills, Distributions, and Average

A number of researchers have reported students having poor graphical interpretation skills and are often unable to reason beyond graphs making connections between the context and the data. Student difficulties when reading and interpreting particular types of graphs, is reported in the literature (Shaughnessy, 2007). Yingkang (2004) study investigated 13 to 15 year old students' ability to read, interpret, construct and evaluate statistical graphs concurrently and found teachers should assist students to correct graph convention errors, help them develop problem solving abilities in statistical graphs, advice them to properly use their contextual knowledge to solve a graph related problem, and guide them to communicate mathematical ideas clearly. Friel et al. (2001) identified three main components for graph comprehension, based on a synthesis of information, involving:

1. The ability to read information directly from a graph based on understanding of the conventions of graph design
2. Manipulating information read from a graph by making comparisons and computations
3. Relating the information in the graph to the context of the situation to generalize, predict, or identify trends.

These authors report research on understanding what makes these three main components difficult for graph readers is needed. Friel et al. report teachers need to consider the instructional sequencing for learning types of graphs, develop understanding of data reduction (e.g., compiling data to discover or create fewer categories), and apply various aspects of graph sense (i.e., creating graphs in a variety of problem contexts).

Some research has been provided addressing appropriate types of graphs for student learning. Carr and Begg (1994) introducing box plots to 11- and 12- year-old students observational study found box-plots are an appropriate topic for students in this age group provided that teachers emphasize the understanding and interpretation of the plots, and not just the construction. However, Bakker et al. (2004) reported delaying the introduction of histograms and box-plots due to the difficulties that middle school students have with proportional reasoning (i.e., quartiles) that is required to interpret these two types of graphs. In a report by Watson (2012a) it is suggested that for students who are struggling in understanding box plots or younger students needing more basic representation there is the hat plot provided in *TinkerPlots*®. Watson (2012b) describes the use of *TinkerPlots*® with Autralian middle schoool students learning the idea of resampling to determine how unusual the difference (e.g., medians) is between to groups. A Sampler tool with the program using *Reaction_Time* randomly collects samples without replacement allowing students to create a History of Results and then graphs comparing differences in reaction time.

Duncan and Fitzallen (2013) suggest an earlier introduction, comparing student time trials in completing a maze activity, to student learning box plots using *TinkerPlots*® given experiences using multiple forms of data representation (i.e., intrepreting column graphs, dot plots, stem-and-leaf displays, and histograms). These authors report the benefits of using box plots and scatter plots earlier in the curriculum, in providing students time to develop exploratory data analysis strategies and fundamental intuitions about working with data before focusing on formal statistical interpretations.

Fitzallen (2013) studied student understanding of graph skills when constructing plots using *TinkerPlots*® suggesting the active role of teacher scaffolding in supporting student graph development and data analysis. Fitzallen studied learning strategies of 12 11-12 year old primary school aged Australian students, over a six week period, using *TinkerPlots*® to construct graphical representations. Fitzallen found that students displayed three dominant strategies when working in pairs through a sequence of learning experiences that introduced elements of *TinkerPlots*® for graph creation and data analysis, as well as the fundamentals of graph intrepretation:

1. **Snatch and Grab:** Students accessed elements in a random manner and had incomplete knowledge about the potential of the program to support data analysis activities.

2. **Proceed and Faltar:** Students used the program purposefully as a construction tool creating graphs with confidence, but often made responses indicating why the respresntations were useful.
3. **Explore and Complete**: Students effectively used the program to support the interpreation of graphs with question responses and graph descriptions conveying intuitions developed about graphing shaped by the data representations.

Fitzallen reports the three strategies show the different ways students worked within the *TinkerPlots*® learning environment and have implications on the active role of the teacher in establishing and supporting the development of student thinking and learning. The study found that having an understanding of how students use interactive software would inform teachers about when to and in what ways to intervene in the learning process.

Further understanding of student graphing interpretations related to data distributions and average using *TinkerPlots*® is discussed by Konold (1989). Konold found students making decisions about single events rather than looking at a series of events. This idea was substantiated later by Konold, Higgins, Russell and Khalil (2004) in a case study of elementary students understanding of data using data analysis software. These authors found that rarely did these students interpret data from an aggregate perspective (e.g., What does this graph show?). Konold et al. (2004) analysis of learning identified four general perspectives that students use when interpreting tool technology data as pointers, case values, classifiers and as an aggregate. Konold found some students are inclined to view data from one particular perspective, which influences and perhaps constrains the types of questions they ask, the plots they generate or prefer, the interpretations they give to notions such as the average, and the conclusions they draw from the data. These authors report the aggregate perspective involves being able to understand and view a complete set of data in unifying with emergent properties such as shape and center. For example, students can understand the concept of average as a label given to a single case or subset, but not as a measure that applies to the entire group. These authors report that students go through acceptable stages in their understanding of statistical data, and that by helping them focus on the values of individual cases in data set students can stay connected to the meaning of the data. Other researchers have reported student misconceptions involving computing averages without focusing on outliers or understanding sampling procedures taken from a larger population (Garfield & Ahlgren, 1988; Shaughnessy, 2007). This research suggests the active role of the teacher will be necessary to support and scaffold student development and understanding of their graphs.

Further research on specific age appropriate types of graphs to facilitate student learning and understanding will be needed, particularily used with technology tools like *TinkerPlots*® or other adaptable software programs, since graphs are critical to evaluating data and developing statistical thinking, reasoning, and literacy. In addition, how teacher scaffolding can support student learning in creating and evaluating graphs will be necessary when using these computer software tools.

Sample Distributions from the Population, Variability, and Central Tendencies

Insight into prevalent ways of student thinking about statistical samples is discussed in the literature. Kahneman, Slivic and Tversky (1982) found student misconceptions when estimating the likelihood, a sample represents or resembles the population. These authors report that errors in reasoning were found in understanding of small samples. Misconceptions were found when beliefs included that small samples should resemble the populations from which they are sampled; so small samples are used as a basis for inference and generalizations. Shaughnessy (2007) reviews of the literature reports students make judgmental errors based on occurrences with neglect to sample size. Misconceptions identified include egocentric impressions of frequency of events biased or based on single occurrences of an event taking on inflated significance when it happens to the person. For example, judgment of likely or unlikely coincidences, subjects thought their own coincidences (i.e., bumping into a friend in a foreign country) were more surprising than coincidences that happen to others. Watson and Moritz's (2000a) survey and follow-up interview study of 11-15-year-old students recognition of newspaper bias found teachers' need to help students become aware of potential sources of bias in sampling, and appreciate the importance of variation in samples and populations.

Distributional student reasoning involving making connections from the populations to samples and averages is presented in the literature. Students' spectrum of intuitive reasoning has been documented in which at one end their thinking is focused on centers and a belief that all samples should be perfectly representative, and the other end too focused on variability with all the possibilities for individual outcomes over or under estimated (Konold, 1989; Rubin, Bruce, & Tenney, 1991). In order for students to reason about distributions and grow beyond a mere focus on expectation, they must develop their intuition for a reasonable amount of variation around an expected value, not just the expected value itself (Shaughnessy, Ciancetta, & Canada, 2003). English and Watson (2015) conducted a longitudinal study of grade four elementary students understanding of variation. Imploying an arm measurment activity evaluation of hand-drawn and *TinkerPlots*® generated representations these authors found that over half (n=115) of the students had developed the ability to transfer and explain the meaning of variation and could detect distribution differences.

The need for student understanding going beyond averaging and comparing data sets to developing conceptual understanding about variability or shape and spread of data has been recommended (Wild & Pfannkuch, 1999; Konold & Pollatsek, 2002; Shaughnessy, 2007). Shaughnessey (2007) reports within the field of statistics variability arises in data, samples, and distributions and students need to develop their intuition for what is a reasonable or an unreasonable amount of variability in these objects. Shaughnessy & Pfannkuch (2002) report students' rush to compute a mean and base prediction on measures of central tendency without even considering what the variability in a data set might reveal about the context.

Support for students to learn and understand central tendencies about data has been reported. This has included measures of center, mode, median and mean, as summary statistics used for a variety of purposes, including helping to describe and analyze data. Friel (1998) reports students need to understand what each of these measures tells about a set of data, and make judgments about when and why to use each measure. Friel recommends students need to analyze one or more sets of data, and be comfortable in knowing how and why they carry out the actual algorithms. According to Friel, understanding develops over time with increasing sophistication when students engage in various problems in a number of different contexts. Students move from conceptual to procedural understanding, able to use the necessary algorithms and to focus their attention on the interpretations of their results based on their understandings of what they know about data given various statistics and representations (Friel, 216, 1998). Watson & Moritz (2000b) interview research study of elementary and middle school students recommend that the teaching of average should build up from students' initial preferences for "middles" and "mosts" to the more normative conception of mean as representative of a data set.

More research and intervention strategies will be needed to support student understanding of population sampling and variability in a data set. This will also include learning opportunities in understanding central tendencies about the data to adequately interpret their authenic project work.

Drawing Conclustions and Questions to Predict Informal Statistical Inference

Students evaluate their data set of information gathered in a research project in order to write conclusions about the findings. As they describe data, based on graphed interpretations, they attempt in developing additional questions making inferences generalized to a larger population. Student generalizations about their research project demonstrate informal inference thinking. Discussion by researchers is presented discussing interventions and methods to promote student prediction skills in developing informal statistical inference.

Watson and Moritz (1999) interview study of 88 Austrailian students in grades 3 to 9 required students to compare the performance of two classes on a test. These authors report the importance of using comparison of data sets to build early experiences in learning statistical inference has not been overlooked for classroom use. For examples curriculum for elementary schools have included activities comparing student shoe sizes, heights of first and fourth graders, paper clip blowing game outcomes, and sugar content in cereals. For older students' investigations have included comparing of of newspaper sentence length, determining if practice improves estimating skills, evaluating sports teams and using starter questions (e.g., Do children eat more sweets than adults?) in the context of describing data, generalizing or making predictions. These authors found students used numerical and visual strategies, either individually or in conjunction with each other, to make comparisons between the data sets presented in graphs. Watson and Moritz report both numerical and visual strategies have their place in statistical analysis and it is important for teachers to encourage using each to reinforce an initial judgement based on the other or point out where one may be more appropriate for use than the other. In this study student use of statistical mean for comparison was used on a limited basis, rather than the visual strategy, when comparing groups. These authors report this may suggest that mean should be introduced later at the elementary level to develop a deeper understanding of the concept and its applications.

Ben-Zvi (2006) describes use of *TinkerPlots*® with teacher scaffolding involving students collecting data about themselves and peer students compared to a UK Census at School database. Ben-Zvi found, based on pre-post tests, significant improvements in students' understanding of informal inference and developing knowledge of statistical ideas. This was supported by Watson's (2008) study of informal inference using box plots with grade 7 students finding evidence of change on the part of students' appreciation of decision making with data, as well as the potential for *TinkerPlots*® to assist in the process.

In a study of third-grader in Cyprus inferential reasoning Paparistodemou and Meletiou-Mavrotheris (2008) found students were able to express informal inference generalized to a larger population. This was achieved by student authenic developed projects (i.e., questionnaires on health) along with utilization of *TinkerPlots*® supporting scaffolding and extending children's informal statistical reasoning. A later study supporting students understanding of sampling representation and variability to make valid inferences regarding population characteristics is provided by Meletiou-Mavrotheris and Paparistodemou (2014) study. The study implemented a three-phase inquiry-based learning environment (i.e., referred to as a hypothetical learning trajectory or HLT) in a Cyprus grade 6 classroom, which included a student developed research study collecting data through a survey sample with analysis using *TinkerPlots*®. The authors reported the class as a whole showed, by the end of the experiment, improved understanding of sample size, potential sources of bias due to sampling design, legitimacy for simple random sampling, and sample stratification as a means for increasing sampling representativeness for some population attributes. According to Meletiou-Mavrotheris and Paparistodemou, when given the chance to participate in an appropriate instructional setting (i.e., HLT learning context and conducting a study on a topic of interest) students can exhibit well-established understandings of sampling issues and other fundamental concepts related to statistical inference.

Based on their review of the literature Garfield, Le, Zieffler, and Ben-Zvi (2015) suggests providing project-based learning with authentic data problems requiring student metacognition and using dynamic data investigation tools. These authors suggest informal learning approaches in early elementary education include approaches such as "growing a sample" activities and utilizing innovative technology like *TinkerPlots*®. Ben-Zvi, Bakker, and Makar (2015) describe "growing a sample" as an approach where students are gradually introduced to increasing sample sizes taken from the same population and asked to make an informal inference for each sample. Watson and Wright (2008) suggest building informal inference with *TinkerPlots*® in a measurement context with students in grades 6 to 10 through investigation activities using a research procedure involving setting the question, collecting data, representing data with *TinkerPlots*®, summarizing data, discussion of sampling questions (i.e., ways to randomly choose a sample) and drawing conclusions. Extension investigations are also provided comparing measurements on two groups and on two variables.

Makar (2013) reports informal teaching of inference can be taught to middle school students when designing learning environments through a "bottom-up" approach taking into account not only what students need to learn, but also their everyday experiences with prediction and inference. Makar describes middle school classroom investigation teaching students about making inferences from data about flight. In this investigation students had to collect data on five flights for a simple loopy plane (i.e., straw and paper strips) measuring the distance for the best design. Using *TinkerPlots*® to record the data from flights, for each student plane in the classroom, conclusions were made on which designs had the longest measured flight. Makar suggests other statistical inquiry questions to promote learning of informal inference in the report.

Watson and Donne (2009) study explored the use of *TinkerPlots*® when interviewing, observing, and collecting work samples of students aged 11-14 years about their approaches to beginning inference. The study used a ptotocol, comparing the *TinkerPlots*® group with paper-based graphs associated with inference in the Watson and Moritz (1999) study. Watson and Donne (2009) found the *TinkerPlots*® format was more efficient for exploring students' understanding of finding evidence for associations (comparisons) of variables and beneficial in providing flexibility for students to display their understanding. Based on their study these authors recommend opportunity for classroom discussion if students are allowed to create their own plots and then share them with each other and state:

> Interpreting each others' plots would be excellent experience for both the reader and the creator of plots (Watson and Donne, 31, 2009).

According to Watson and Donne, a report supplementing the plots with text boxes include observations, suggestions, and hypotheses based on data set findings. It is also recommended that a check list be used at the beginning of the studies interviewing students to assess which *TinkerPlots*® tools are familiar to the student and which are not.

Ben-Zvi, Bakker, and Makar (2015) report on studies regarding students' understanding of samples and sampling when making informal statistical inferences and instructional approaches to promote understanding of statistical inference. Based on these studies these authors support authentic experiences in collecting data through survey and experiences using simulation tools (e.g., *TinkerPlots*®) to help students develop understanding of sampling and informal inference.

The following topics have been discussed to develop student statistical literacy including graphing data to interpret distributions and central tendencies; sampling and variability from the population; and drawing conclustions for predicting informal statistical inference. Use of statistical software-based programs like *TinkerPlots®* provides support to students to evaluate data set findings and make inferences. Khairiree and Kurusatian (2009) found *TinkerPlots®*, if appropriately employed as a problem-based learning tool, can be effective in enhancing active learning and students' understanding of statistics.

Other more fundamental mathematical conceptual literacy considerations will need to be considered and discussed by Garfield and Ben-Zvi (2007). These authors report students have difficulty with many statistical ideas and complex rules underlying mathematics (e.g., fractions, decimals, proportional reasoning, and algebraic formula) that interfere with learning related statistical concepts. According to Garfield and Ben-Zvi, the content of statistical problems causes faulty intuitions rather than using data-based evidence, and students feel uncomfortable with the "messiness of data" creating different possible interpretations. Attention to students' statistical conceptions and beliefs will be necessary, since research is showing many teachers unconsciously possess a variety of misconceptions that might be shared with students (Rubin & Rosebery, 1990; Makar & Confrey, 2004).

Providing Teacher Support for Implementing a Statistics Curriculum

Teacher Conceptual Understanding and Attitudes

Teacher's poor understanding of the content, concepts, and ideas about statistics, along with methodology issues is problematic for teachers (Garfield & Ahlgren, 1988; Russel, 1990; Hawkins et al., 1992). Teachers need support at several levels to effectively implement a statistics curriculum for students. The literature review examines teacher attitudes and beliefs toward statistics teaching, the need and areas for training, elements for providing curriculum support, curriculum delivery considerations, and use of *TinkerPlots®* technology for staff development.

Attitudes and beliefs are important considerations for preparing teachers to teach statistics. There is considerable research to indicate that teacher attitudes about mathematics influence their learning and teaching of mathematics (Nespor, 1987; Thompson, 1992; Richardson, 1996; Hart 2002). Ball states that people's understandings of mathematics are interrelated with how they feel about themselves and about mathematics (Ball, 461, 1990). Battista (1986) study found that learning a mathematical pedagogy could reduce the mathematics anxiety of preservice elementary teachers. Nespor's presentation of the model of beliefs suggests if we are interested in why teachers organize and run classrooms as they do we must pay much more attention to the goals they pursue (which may be multiple, conflicting, and not at all related to optimizing student learning) and to their subjective interpretations of classroom processes (Nespor, 325, 1987). Thompson states research on teachers' beliefs has made clearer to us that no simple model of teaching and learning can be used to account for teachers' and students' actions in the classroom (Thompson, 142, 1992).

Mills (2008) survey study of elementary and secondary teachers' attitudes about statistics found grade 6-8 teachers reported being more comfortable teaching statistics than P-K teachers, and slightly more comfortable than grade 1-5 teachers. Mills also found teachers who agreed that they like teaching statistics, and are more comfortable doing so, had more experience with statistics training. This study indicates that how much statistics experience a teacher has had probably affects their attitudes and perceptions. Mills reports the most important implication for educators is that teachers reported they need additional training, and that they have difficulties understanding statistics concepts. Some of the major topics teachers reported least comfortable in teaching included probabilities, standard deviation, word problems, hypothesis testing, and correlation. Mills states that most teachers reported that developing and evaluating inferences and predictions that are based on data was the most difficult to implement (Mills 6, 2008).

The need for a curriculum model and methodology that provides adequate support for teachers is discussed in the literature. Hawkins, Jolliffe and Glickman (1992) survey of UK teachers report most respondents enjoyed teaching probability and statistics, but found that a scientific methodology was needed when data is evaluated and processed. Russell (1990) found a stumbling block for teachers using an elementary number collecting and analyzing real data number program was the lack of confidence and knowledge about the procedures and problems they gave their students. Russell reports there are few models or experiences for teachers to draw on for collecting, representing, or describing a particular set of data. Russell says it is difficult for teachers to change the way they teach math without models, images and experiences to guide them. Another problem area identified by Russell is teachers' inability to recognize and respond to students' solutions and interpretations.

Teachers feel uncomfortable teaching statistics concepts because they have not been adequately trained, and many of the teachers have either never taken a formal statistics course or had very little formal training (Begg & Edwards, 1999; Franklin, 2000). Groth and Bergner (2006) studied preservice elementary teachers' conceptual and procedural knowledge of mean, median, and mode. These authors found a majority of teachers exhibited limited understanding displaying syntactic and algorithmic procedural knowledge with concepts interferring with attaining concepetual understanding.

Professional development activities are probably the most important resource for teachers to improve meaningful knowledge of content and attitudes toward mathematics (Battista, 1986; Ball, 1991; Hill & Ball, 2004; Quinn, 1997). Schoen, Cebulla, Finn, and Fi (2003) found similar results, and that completion of a professional development math workshop course was positively related to growth in student achievement. Watson (2001) use of an information profile to assess the need for professional development found teachers' lack confidence in statistics and lacked knowledge about sampling. These teachers also reported needing professional development in data and chance.

Intervention Strategies to Support Training

Ideas addressing the most appropriate context for delivery of a statistics curriculum, along with providing a stochastic learning environment, are suggested. A consideration in teaching data analysis reflects the differences between mathematics and statistics, and how statistics is a separate discipline. Support for describing statistics as a separate discipline from mathematics as a science through gaining insight from the context of data and requiring use of different types of reasoning is documented (Rossman, Chance & Medina, 2006; Cobb & Moore, 1997; delMas, 2004). Implications for this difference suggest experiences in the statistics classroom focusing more on stochastic processes and ideas rather than computations and procedures; students experiencing first hand the process of data collection and exploration; and including experiences promoting discussion on how data is produced with selection of appropriate statistical summaries to support drawn conclusions (Landwehr & Watkins, 1986; Friel, 1998; Moore, 1998; delMas, 2004; Rossman, Chance, & Medina, 2006). The separate discipline argument with regard to teaching methodology was found in an experiment to assess new strategies for teaching statistics at the secondary level in Italy, in which Gattuso (2002) reports teachers trained in mathematics taught statistics using a mathematical approach rather than as a teaching style appropriate to statistics. Statistics is much more closely related then mathematics to other sciences (i.e., linguists or geography to physics, engineering or economy) where it is used as the language and method of scientific inquiry, and from which many statistical methods were developed (Franklin & Newborn, 3-4, 2006). In a similar position Starkings (1993) suggests that issues relating to the teaching of data analysis are important to teachers of a wide range of subjects across the whole curriculum. In most educational establishments data analysis does not exist as a subject in its own right (Starkings, 104, 1993).

Staff development for teacher use of technology tools, like the *TinkerPlots* program, is needed. Hammerman and Rubin (2003) worked with middle school and secondary school teachers creating *TinkerPlots*® bin graphs to compare different groups. Teachers found many ways to work with the variability of data to make it more manageable. Hall (2009) describes a teacher hands-on exploration workshop using *TinkerPlots*® where participants used real data about their pupils that resulted in positive attitudes toward teaching statistics.

Effective staff development programs will be needed to improve teachers' content knowledge of statistics, address teachers' beliefs and attitudes toward the subject, support use and implementation of a stochastics curriculum, and provide training in the use of technology tools. Training to develop teacher's conceptual understanding of statistics will be necessary as reported by Rubin and Rosebery (1990) suggesting finding teacher's prior notions of statistical concepts that can actually interfere with acquiring a more sophisticated understanding of even basic concepts like median. In addition, teachers will also need training supporting students' not only with statistical techniques, concepts and tools but also with the many nuances, considerations and points of view involved in generating, describing, analyzing and interpreting data and in reporting findings (Ben-Zvi, 2001). Friel et al. (2001) report teachers will also need to increase their knowledge about different types of graphs and learn how to teach graphing skills. According to Rubin and Rosebery (1990) for teachers to gain expertise in statistical reasoning they have to experience "being statisticians" themselves. These authors suggest teachers investigate statistical problems that interest them, collect data, analyze, and draw conclusions the way statisticians would. More research will be needed to evaluate these variables specifically related to providing effective teacher training in statistics to ultimately facilitate students' development of statistical literacy.

Given current information about students' statistical thinking and study of student learning opportunities, supported with technology tools like *TinkerPlots*®, a framework for teacher planning learning goals and designing learning tasks will need to be developed. A framework that is capable of predicting the kind of learning and thinking that will occur as tasks are played out would be most helpful. Mooney's (2002) qualitiative study of students across grades 6 – 8 developing and validating a framework for characterizing students' thinking across four processes: describing data, organizing and reducing data, representing data, and analyzing and interpreting data may serve as a starting point. Providing specific student skill intervention strategies for each process on the framework, based on current research best practices, would have implications for instruction and curriculum design related to learning statistical data analysis.

Supporting teachers in creating a stochastic classroom for students integrating the teaching of statistics using technology tools across the curriculum will require staff development training. The training will need to not only improve teachers' content knowledge of statistics, including the use of technology tools, but also address their attitudes and perceptions about the subject. Specific intervention strategies using teacher scaffolding will need to be provided as students evaluate their data using tools like *TinkerPlots®* to make conclusions and draw inferences.

Is *the Survey Toolkit* Curriculum a Paradigm Fit?

The Survey Toolkit curriculum and *TinkerPlots®* software have been used by the author to provide instruction to students in learning about survey and statistics when teaching grade six high ability students receiving services in the Extended Learning Program (ELP). ELP extends and differentiates the existing grade level curriculum to provide a more challenging and rigorous learning experience for students.
The literature review presented provided support for statistics literacy for all students and teachers. Information was presented to provide the teaching of data analysis across the curriculum (Starkings 1993, Gattuso 2002, Franklin & Newborn, 2006). Numerous authors reported support for teaching statistics to younger students using authenic project-based learning with teacher scaffolding (Ben-Zvi, 2006; Makar, 2013; Paparistodemou & Meletiou-Mavrotheris, 2008; Meletiou-Mavrotheris & Paparistodemou, 2014; Garfield, Le, Zieffler & Ben-Zvi, 2015; Ben-Zvi, Bakker & Makar, 2015). Use of technology tools using *TinkerPlots®* for students to develop graphs and compare data plots in order to draw conclusion and make inferences was presented (Konold, Higgins, Russell & Khalil, 2004; Ben-Zvi, 2006; Watson, 2008; Watson & Wright, 2008; Watson & Donne, 2009; Khairiree & Kurusatian, 2009; Watson, 2012; Duncan & Fitzallen, 2013; Meletiou-Mavrotheris & Paparistodemou, 2014; Garfield, Le, Zieffler & Ben-Zvi, 2015; Ben-Zvi, Bakker & Makar, 2015), along with providing staff development to teachers (Hammerman & Rubin, 2003).

Implementation by the author in using the *The Survey Toolkit* and *TinkerPlots®* with grade six students for fives years, with over 100 students, has resulted in development of poster display projects on numerous topics (refer to Figure 4) based on their interests. Given support in the

Figure 4. Research Question Topic Ideas Selected by Middle School Students (Author, 8, 2011)

Science and Technology	**History and World Cultures**
Aircraft	Ancient China
Aviation Progression	Ancient Egyptian Cultures
Alternative Fuels	Ancient Egyptian Gods and Goddesses
Astronomy	Ancient India
Constellations	Confucianism and Taoism
Flying Devices	Easter Island
Energy and Machines	Egyptian Mythology
Energy Sources (Forms)	Famous People of Medieval Times
"Green" Environment	Foods of the Renaissance
Hovercrafts and Segways	Greece / Greek Mythology (Gods)
Inventions	Rome
Light Reflection and Sound Waves	Han Dynasty
Math and What People Like About It	Hinduism
NASA: The Founding and Space Pilots	History of the Renaissance
Nanotechnology	Medieval Music
Natural Disasters	Medieval Period and Castles
Physics: Work, Energy and Power	Medieval Siege Weapons and Castle Defenses
Planets	Roman Infantry
Rockets	Spartan's Weapons
Simple Machines	Travel Destinations

Solar Energy	Tudor Dynasty
Space Exploration	**Health, Psychology, and Nutrition**
Technology Advances	Brain and Hemispheres
Virtual Reality Machines	Brain and Nervous System
Volcanoes	Eyes and Vision (Ophthalmology)
Weather	Healthy Choices
	Nutrition and Exercise
	How Color Affects People (Mood)

literature for student authenic project-based learning on topics of interest using "real data," use of this curriculum, partially or in its entirety, may serve as a viable option for educators.

The Survey Toolkit Curriculum Integration with *TinkerPlots*®

This instructional program is a project-oriented learning curriculum on research methods developed primarily for elementary to middle school age students based on study of research instructional design methodology at Iowa State University. The program has been field-tested with the author's regular grade three students and grade six gifted education students for over 10 years. The research method was found effective in guiding students in choosing a research question, writing a research report using a cluster paragraph information collection strategy, developing unbiased questions for giving a survey to a reliable sample, analyzing survey data using *TinkerPlots*, and sharing results on presentation boards. *The Survey Toolkit* curriculum was found to be applicable for researching topics across the curriculum.

The Survey Toolkit lessons and activities follow research sequence students follow to successfully complete a survey project. The text was organized based on the scientific method and follow a research methodology supported by Borg and Gall (1989). These texts provide a methodology for students and teachers to follow for developing a survey research project using *TinkerPlots*®, and are described in Figure 5. *TinkerPlots*® is a tool technology in which students enter survey data into data cards and create graphs to analyze and show findings from their research study, which provide support in writing a final report with a conclusion and inferential

Figure 5. The Survey Toolkit Lessons Plans and Activities Listed in the Table of Contents

Part 1. Choosing a Research Question
- 1.1 Introducing Surveys
- 1.2 Looking at Survey Data
- 1.3 Planning and Setting Goals
- 1.4 Finding Information
- 1.5 Summarizing Information

Part 2. Developing and Giving the Survey
- 2.1 Writing Survey Questions
- 2.2 Choosing a Sample
- 2.3 Writing a Hypothesis
- 2.4 Finishing and Giving the Survey

Part 3. Analyzing Survey Data
- 3.1 Representing Survey Responses
- 3.2 Entering Data into TinkerPlots
- 3.3 Exploring Categorical Attributes
- 3.4 Exploring Quantitative Attributes
- 3.5 Comparing Attributes

Part 4. Sharing Results
- 4.1 Writing Findings and Conclusions
- 4.2 Summarizing Your Research
- 4.3 Making a Poster or TinkerPlots Report
- 4.4 Writing a Report (Author, 4-5, 2011).

questionning. Refer to Author (2011) *Journal of Statistics Education* (JSE) article for further information about the development, implementation, and use of the curriculum with students. The survey curriculum program is available as follows:

- *The Survey Toolkit* is available by contacting MHE by email @ orders_mhe@mheducation.com and providing the ISBN #978-1-55953-886-2.
- *TinkerPlots* is available at the University of Massachusettes for ordering @ http://www.srri.umass.edu/tinkerplots/.

The Survey Toolkit Resource Manual is an unpublished manuscript used with the author's students to support and provide background reading and activities for *The Survey Toolkit* text. The manual includes additional activities and materials to support delivery of the curriculum. The readings provide students with additional information about key concepts and vocabulary involved in conducting survey research. The manual includes a staff development plan for *The Survey Toolkit* and *TinkerPlots*® teacher training. Student project examples are shown to provide additional conceptual understanding. The resources are available for use at the JSE website. Click on the link below to download the 88 page *The Survey Toolkit Resource Manual.*

http://www.amstat.org/publications/jse/v19n1/SurveyToolkitResourceManual2011.pdf

The literature review link, published in the JSE publication, is not longer active since the information is provided with this journal report publication.

Implications of a Statistics Curriculum and Further Research Directions

Given support for an authenic learning experiences for students in learning statistics using curriculums like *The Survey Toolkit*, the literature review presents further questions regarding how to address student learning issues and supporting teachers in implementation of a statistics curriculum. Given a curriculum using *The Survey Toolkit* with *TinkerPlots*® for developing project-based learning, teacher scaffolding support will be necessary for student success in:

- Constructing appropriate plot graphs of collected data (e.g., When should students create a box plot?),
- Creating graphs from an aggregate perspective to evaluate inference,
- Evaluating data plots, which support student research questions for writing conclusions,
- Increasing awareness of potential sources of bias in sampling,
- Appreciating and understanding the importance of variation in samples and populations.

Support to successfully guide student learning will be required for teachers in the following ways:

- Understanding of the content, concepts, and ideas about statistics, along with methodology curriculum issues
- Addressing attitudes, beliefs, and comfort level for preparing teachers to teach statistics,
- Training teacher use of technology tools, like the *TinkerPlots* program,
- Creating a stochastic classroom to recognize and respond to students' solutions and data plot interpretations.
- Integrating the teaching of statistics project work across the curriculum or among teacher teams providing instruction in different subject areas.

Supporting teachers in creating a stochastic classroom for students integrating the teaching of statistics using technology tools across the curriculum will require staff development training.
Effective staff development programs will be needed to improve teachers' content knowledge of statistics, address teachers' beliefs and attitudes toward the subject, support use and implementation of a student developed research project, and provide training in the use of technology tools.

Further research investigations have reported goals and specific learning skills for instruction in statistics education. These propositions and topics students should learn have provided some guidelines for developing an effective statistics literacy program. More recent research addressing student misconceptions in statistical thinking and pedagogy issues, including use of technology tools like *TinkerPlots*®, suggests areas in the curriculum where teacher scaffolding will be necessary to support student learning. Teachers' attitudes and understanding of concepts indicates the need for appropriate staff development experiences for successful implementation of a statistics curriculum using data generating tool programs like *TinkerPlots*®.

According to (Ben-Zvi, Bakker, and Makar (2015) that despite the emergence of innovative learning environment and curricula there is still not enough research on the ways it can be used to support the emergence of students' statistical reasoning effectively and efficiently and how to assess them. We also do not know much about teachers' understanding of these issues or how they can assist their students in developing these ideas.

Given resources like the *The Survey Toolkit* and resource nanual, providing a written narrative of data analysis concepts along with student examples, will need to be evaluated in developing student understanding of concepts and teacher attitudes in implementing this type of stochastic curriculum. The staff development plan and use of the manual with teachers will also need to be studied to determine if this resource promotes implementation of an effective statistics curriculum. In addition, do the lesson plans and student activities in *The Survey Toolkit* provide adequate teacher support and scaffolding to promote student understanding of critical concepts and skills, including use of *TinkerPlots*®? Finally, further research and effective use of technology tools like *TinkerPlots*® with students and teachers will also need to be explored as it is used in this curriculum context.

CONCLUSION

The study of probability and data analysis is historically rooted emerging out of other disciplines leading to support from NCTM and other organizations. These organizations and projects have lead to development of a movement supporting a statistics curriculum in the schools with literacy at all levels. A historical perspective in the development of statistics education as a discipline leading to the need for statistical literacy at all levels in a technology-based society was presented. Support and need for statistics learning due to widespread use, influence of technology development and social media used to persuade public opinion and traffic fake news was discussed. National guidelines and projects for developing a statistics curriculum were examined.

Student content knowledge and skills including important topics for study in teaching a statistics curriculum was provided, along with student learning considerations. Use of technology tools, like *TinkerPlots*®, for student use in promoting informal inference was presented providing insight into effective learning practices and support using teacher scaffolding. Teachers' attitude about teaching statistics along with pedagogy issues, including the need to provide staff development using *TinkerPlots*®, was explored.

Consideration of *The Survey Toolkit* currriculum using *TinkerPlots*® was evaluated as a potential viable methodology to use for student project-based authentic stochastic learning. The curriculum was also discussed as a possible tool for teacher staff development training. Finally, implications of a statistics curriculum used with younger students and further research directions were suggested based on the literature review and implementation of *The Survey Toolkit* currriculum by the author's students.

Given the current trafficking of misinformation and fake news it is imperative more than ever to provide students' learning experiences and skills applying fundamental principles of statistics in development of authenic research projects. *The Survey Toolkit* and *TinkerPlots*® curriculum teaching research collecting skills and information gathering techniques in the context of learning statistics may serve as an appropriate entry program for elementary and middle school students.

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