



## **Integrating Real-Life Data Analysis in Teaching Descriptive Statistics: A Constructivist Approach**

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*Journal of Statistics Education* Volume 18, Number 1 (2010),  
[www.amstat.org/publications/jse/v18n1/libman.pdf](http://www.amstat.org/publications/jse/v18n1/libman.pdf)

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**Key Words:** Constructivism; Statistics Education; Alternative Assessment

### **Abstract**

This article looks at a process of integrating real-life data investigation in a course on descriptive statistics. Referring to constructivist perspectives, this article suggests a look at the potential of inculcating alternative teaching methods that encourage students to take a more active role in their own learning and participate in the process of assessing what they have learned. The article illustrates how this teaching method enabled students to realize that imparting meaning to sets of data is a complex activity which involves conceptual flexibility, integration of all the procedures that one has learned, and creative reasoning.

### **1. Introduction**

As educational reforms lead to additional changes in statistics education, innovative and effective instructional strategies will continue to be a challenging endeavor, especially for "occasional users" taking statistics as a service course in preparation for their professional career ([Garfield, Hogg, Schau, & Whittinghill, 2002](#); [Moore, 2001](#); [Nicholls, 2001](#)). This article looks at a process of integrating real-life data investigation in a course on descriptive statistics at a teachers college. Theoretically, it is based on the constructivist view of learning which

encourages teaching that allows students to construct meaning. The article describes the process of teaching that was used in this course, which required students to cope with assignments based on real-life data. Essentially, this article considers implications of this constructivist based approach in terms of its potential to improve the quality of learning descriptive statistics.

The article has four parts. The first consists of a brief discussion of constructivist theory and its application to teaching, evaluation and learning. The second part addresses *context* and its relevance to learning. The third and main part presents the process of integrating authentic data analysis in teaching descriptive statistics and highlights insights that arose while the course was being taught. And finally, the fourth part sums up the article and offers some implications.

## **2. Constructivism – Teaching, Evaluation, and Learning**

Constructivism is a theory about knowledge and learning that deals on the conceptual level with the question of the nature of knowledge and how a person comes to be a "knower" ([Bereiter, 1994](#); [Bransford, Brown, & Cocking, 2000](#); [Driver, Asoko, Leach, Mortimer, & Scott, 1994](#); [Fosnot, 1996](#); [Laroche, 2007](#); [Prawat, 1996](#)). Based on research in psychology, philosophy, and anthropology, constructivist theory describes knowledge as time-bound, evolving, and subjective. It is constructed *within* the person as a function of social-cultural processes. From this angle, learning is seen as a process of self-regulation – or actually as a struggle between the person's currently held beliefs and attitudes, and different, sometimes even clashing, conceptualizations. As a result of this struggle the individual constructs a different representation of reality which is more meaningful to him or her. We could contrast, in general terms, the "old" positivist approach with the new "constructivist" one: in the older approach, knowledge is considered static and separate from the knowing subject. Truth, or "truths", are situated outside the knower, and knowledge consists of the accumulation of truths in a particular subject area. The more such truths a person collects, the more knowledge he has. Constructivism sharply opposes this view and claims that knowledge is created by the knowing subject as a function of beliefs and experiences. Since knowledge consists of what human beings do and express, it is always tentative, subjective and personal. It cannot be proven true in any absolute sense. Hence, constructivism does not posit a structure of universal truths. Rather, constructivism refers to *working hypotheses*.

Though constructivism is not a theory of teaching, it has powerful implications for teaching and evaluation whose results may be very different from what usually happens in educational institutions. From a constructivist viewpoint, the traditional, positivist model of "teaching as transfer of knowledge", where teachers work with the assumption that they can directly pass on knowledge and understanding to their students and then evaluate whether they have accomplished their aims, is invalid. Constructivists would argue that we cannot assume that meaning can simply be conveyed to students through symbols, formulas and explanations, nor can students acquire exact copies of their teachers' concepts. Moreover, constructivists claim that concepts cannot efficiently be broken down into sub-concepts, or taught without reference to context. By contrast, a constructivist approach to these matters offers students the opportunity to construct meaning by and for themselves, immersed in context-bound experience in which they

look for patterns, raise questions, build models, strategies and approaches ([Airasian & Walsh, 1997](#); [Fosnot, 1996](#); [Larochelle, 2007](#)).

In the past 25 years constructivism has swiftly gained prominence. Most recent curricular reforms, especially in mathematics and the sciences, have referred to constructivism, either explicitly or implicitly. In the 1980s, the National Council of Teachers of Mathematics published a position paper which describes mathematics teaching as, among other things, encouraging students to construct their own problems ([NCTM, 1980, 1989, 1995](#)). Similarly, the National Science Education Teacher Association suggests a science research approach by which students develop and conduct their own experiments and study their research hypotheses ([Van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005](#)). Institutes for higher education, too, have often mentioned the importance of the constructivist approach to teaching and evaluation ([Biggs, 1996](#); [Hendry, 1996](#); [Tynjala, 1999](#)), especially in science and medicine departments ([Kirschner, Sweller, & Clark, 2006](#); [Schmidt, 1998, 2000](#)), as well as in statistics education ([Broers & Imbos, 2005](#); [Chance, 1997](#); [Cobb, 1993](#); [Garfield, 1995](#); [Garfield et al. 2002](#); [Groth, 2007](#); [Hogg, 1992](#); [Moore, 1997](#)).

In summary, it can be said, that theoretically there is general agreement about the constructivist aspect of human learning. The experience that this article describes focuses on the importance of context in learning and evaluation. This idea will be elaborated in the next section.

### **3. The Importance of Context in Learning**

We chose to teach the topics of descriptive statistics with special emphasis on context, both in the learning stage and in the subsequent evaluation of what had been learned. During the course the students practiced what they were learning by performing analyses of data they collected themselves. These exercises formed a significant part of the course evaluation. Exercising the study material with reference to authentic data added a dimension of significance and challenge. In this way, we believed, students would learn something beyond mastery of statistical procedures. Constructivist theory strongly implies that gaining deep understanding, which will then enable the student to properly apply what he has learned, requires a mode of learning that allows the learner to investigate freely, in realistic circumstances and meaningful contexts (see, for instance, [Fosnot, 1996](#); [Resnick, 1989](#); [Larochelle, 2007](#)). This actually involves two requirements: personal investigation, and complex and meaningful context. Contextual learning, to a substantial degree, dictates teaching and evaluation methods that require the learners to do their own investigating and cope by themselves in order to create meaning, in this case – statistical understanding.

Five main features that are typical of authentic contexts have been suggested ([Cobb, 1999](#); [Fosnot, 1996](#); [Tynjala, 1999](#)). These features are the theoretical justification for including authentic contexts in processes of teaching and evaluation, and they are as follows: practical significance; complexity and challenge; relevance and motivation; interconnectedness and transfer and learner empowerment. Though these features are fundamentally interlinked, For the sake of clarity each of them will be described separately.

### **3.1 Practical significance**

The initial argument is that there is no context-free learning. Knowledge is situated and context-bound ([Lave & Wenger, 1991](#)). This implies that the studied information should be connected to real-life situations in which students are likely to use it. The challenge for the educational process then is not that of storing facts, theories and formulas. Rather it is to generate the kinds of contexts in which the value and meaning of the subject matter in question i.e., descriptive statistics, may be most fully realized. Thus, "concepts and principles may be linked to the ongoing practical pursuits of persons or communities" ([Gergen, 1995, pp. 35](#)).

### **3.2 Complexity and challenge**

A second argument is that a learning situation that encourages personal investigation in a real-life context is rich and complex; it does not prescribe one correct way of learning about reality, or one correct answer ([Kirschner et al., 2006](#)). In real life, events always present a wealth of data and conditions which can be investigated from a variety of angles and learned from plural points of view. Moreover, when a teaching situation is sufficiently and appropriately complex it constitutes an intellectual challenge and is more likely to hold the learners' interests and bring them to invest energy and thought. For complexity often teases out curiosity and interest. When presented with a complex learning situation of statistical subjects, students can come up with their own questions, evolve their own models and explanations, and examine their own output ([Fosnot, 1996](#); [Garfield & Ben-Zvi, 2007](#)).

### **3.3 Relevance and motivation**

The notion of relevance refers to the fact that at some point in the course of teaching, the students should actually come to regard the problems as their own problems. This will cause them to personally evaluate the studied concepts and principles. Contextual teaching and evaluation of descriptive statistics, as a result, are likely to motivate the learners to construct, or to change and reconstruct their previous (mis)conceptions. The assumption is that if students are working for themselves and they have a clear notion about the relevant context of the knowledge, they will want to acquire this knowledge. In other words, if one is to solve a problem intelligently, one must first regard the problem as one's own, as an obstacle on the path. Only then can he harness his energy so as to invest what is necessary in order to acquire deep understanding of the subject matter and readiness to use it ([Driver et al., 1994](#)).

### **3.4 Interconnectedness and transfer**

The fourth argument concerns the importance of authentic context for the application and transfer of learned material, i.e., the ability to use what has been learned and acquired for solving new problems.

Researchers believe that constructivist theory is important because it perceives the context of teaching as interconnected and complex, as ill-structured and irregular. When this is acknowledged learning processes that allow development of greater cognitive flexibility can be assimilated – and this, in turn, helps the learners develop their ability to implement knowledge. Complex and realistic contextual teaching and evaluation conditions are likely to encourage more meaningful statistical reasoning and conceptual understanding. Such conditions provide experience in applying the concepts and rules that have been learned. They also illustrate how the nature of the problem dictates the modes of solution. This facilitates application and transfer: students learn how, each time, to come up with an appropriate combination of rules and how to use these rules for problem solving ([Gergen, 1995](#); [Hmelo-Silver, 2004](#); [Kirschner et al., 2006](#)).

### 3.5 Learner empowerment

Teaching and evaluation processes that encourage personal investigation in a realistic context reinforce the role of the learner ([Eisner, 1999](#); [Graves, 2002](#)). Traditionally it is the teacher exclusively who decides what will be taught and how the student will be evaluated. What it comes down to is that the teacher usually has a fixed plan in which the student has no say. When, however, teaching and evaluation conditions include students' personal investigation of statistical data in a practical-personal context, the student, to an important extent, becomes a partner in selecting subject-matter to be studied and evaluated and the curriculum is no longer fixed and rigid. In such a teaching-evaluation framework, the students have a role in adjusting the curriculum to their needs, because the conditions of discussion and learning demand it. More dialogue, too, is possible, in this type of setting, between teacher and learners, as well as among the learners themselves. Since the students are familiar with the situation they are investigating and studying, they become sort of experts who may initiate, pose questions and problems, and raise topics for discussion. Thus the student comes to own knowledge regarding the topic under investigation and may gain a decisive voice in the course of the lesson, its outcomes, and the mode of evaluation in use.

To conclude this section, it should be pointed out that constructivist theories make no hard and fast distinction between teaching and evaluation ([Eisner, 1999](#); [Shepard, 2000](#)). Evaluation is seen as integral to teaching because it accompanies and moulds learning processes at every stage. According to this approach the process of learning is no less important than its outcome. What matters here is the alignment between teaching methods and evaluation, or *instructional alignment*, as it is known among professionals ([Cohen, 1987](#); [Nitko, 1989](#)). According to this notion, teaching is a complex system, all of whose components are aligned in order to maximize the most important goal: improving student learning.

## 4. Integrating real-life data analysis

In the study groups that this article describes, the students learned descriptive statistics by practicing the acquired subject matter on real-life data they collected according to their choice. During the first lesson of the semester, students were instructed about data collection on a topic of interest to them. They were told that they would be expected to investigate and describe the data they collected with the help of the tools for statistical analysis they would acquire in the

course. They were also told that the quality of their analysis and the effort they invested in the analysis would play an important role in determining their final grades.

Three study groups (a total of about 300 students), who were taught by three teachers and three teacher-assistants, participated in the study. Each teacher taught the lesson in his or her way. At the end of each lesson, the teacher gave the students a homework assignment. While, however, the exercises usually used in introductory statistics are the kinds that appear in regular statistics textbooks, participants in the current study were asked to perform the statistical analyses with data they had collected themselves. An example of a typical exercise in frequency distributions tables presented in a textbook might look like this:

***There were 50 items in a mathematics test. For each correct answer, students received one point. The following is a list with the marks of 40 students.***

***Prepare frequency distribution tables in two forms:***

***(a) Using a class interval of 6***

***(b) Using a class interval of 3***

***Indicate the advantages and disadvantages of each type of representation.***

In contrast, the study groups who were practicing descriptive statistics with real-life data were asked the following open question:

***Referring to your data, formulate a question (or questions) that interests you concerning one of your variables, and that can be answered by means of two different frequency distribution tables. Write down your question, answer it and draw the necessary conclusions.***

When students work with this type of evaluation task, they "use their minds" and they are active twice over: (a) they formulate questions, and (b) they organize and apply the studied material in a context that is real and significant for them. Given, in fact, the current nature of studies in higher education, this kind of teaching is most similar to the one they will encounter at a later stage, when they will be expected to analyze data by themselves.

The crux of this article is to clarify the insights that arose when we examined students' exercises, and how they affected the classroom teaching. Below are examples from students' exercises which aim to illustrate the advantages of this teaching-evaluation method. But before going into a more analytical discussion of students exercises in this learning situation, one example of student activity will be presented in greater detail.

This student set out to analyze theater attendance of people in a large community center where he worked. He compiled a short questionnaire, which included the following variables: age, gender, occupation, frequency of theater attendance (number of plays seen during the year), type of play preferred and to what extent the subject enjoyed going to the theater. He then circulated the questionnaire to 30 people attending the community center who had been randomly selected. The student then "interrogated" his data on the basis of the course material. He set the following questions:

- What is the distribution of theater attendance of the sample?
- What kind of plays do they prefer?
- Are there differences in the preferences of men and women?

- Is there a correlation between the age of the subject and the other variables?

Following is part of the answer to the first question (frequency distributions of theater attendance) and issues that arose during the analysis:

**Number of theater visits: Frequency distribution of theater attendance**

<b>Class size=5</b>		<b>Class size=3</b>	
<b>No. of visits</b>	<b>Frequency</b>	<b>No. of visits</b>	<b>Frequency</b>
0-4	10	0-2	11
5-9	15	3-5	10
10-14	2	6-8	4
15-20	3	9-11	2
<b>Total</b>	<b>30</b>	12-14	0
		15-17	1
		18-20	2
		<b>Total</b>	<b>30</b>

The discussion concerning the alternative presentations of the data dealt with the following issues:

- What does the distribution of theater attendance look like? Can we draw different conclusions from the alternative presentations of the data? What are the advantages and disadvantages of each of the presentations? Should we present the results in graphic form?
- Are these the expected results? Do you think that if someone else analyzed the data he would get the same frequency distribution?
- Without calculating, which distribution seems to be more "scattered"? Why?
- Without calculating, what measure of central tendency seems to be most appropriate to describe this frequency distribution?

In the next sections some more examples will be described and discussed according to the theoretical framework which defines the five advantages of this kind of intervention: practical significance, complexity and challenge, relevance and motivation, interconnectedness and transmission, and learner empowerment.

#### **4.1 Practical significance**

In the study groups in which authentic tasks were carried out through real-life data investigation, the study process received an added practical significance. In the work of these groups, the message was: Researchers do data analysis when they want to find out something about a specific issue, and not simply because they want to do statistical analysis.

Students chose research topics and collected data that reflected their interests. The study topics were practiced by trying to answer questions the students wanted to consider, and which related to a variety of issues in their personal or professional lives. Trying to answer their own questions was the incentive for students to examine the data in depth and to apply the concepts and principles they had acquired in the statistics course.

Since most of the students at the college were student teachers, they were most interested in the school environment and, especially the pupils in the class in which they were doing their training. Examples of students' choice of subjects included learning achievements of the class they had taught compared to the achievements of other classes, reading habits of pupils in their class in terms of quantity and types of literature, progress in reading skills and physical development of first graders, follow-up of pupils' second language achievements in English and Arabic from fifth to sixth grade, computer accessibility for classroom teachers as compared to their pupils, and leisure activities of pupils at various levels of achievement.

Other subjects of interest related to the teachers in the schools where the participants were trained, such as teacher satisfaction with teaching, and teacher burnout. Other topics, too, were chosen, like for instance, one student collected data at a basketball trainers course in which he had participated, referring to background information about the participants and to their satisfaction with the course. Another student had a look at patterns of theater attendance, and yet another looked at satisfaction with life on the kibbutz in which she lived, with reference to respondents' profession and age.

Students used the data they had personally collected in studying all course topics in descriptive statistics. This, in fact, showed students the practical significance of the concepts they met in their studies and supported the connection between the study process and the skills that would be demanded of them in the future: to be able to collect and describe data with the aim of answering a specific question. As the students in this group progressed, they answered concrete questions which they themselves had formulated.

## **4.2 Complexity and challenge**

A learning event in which students examine real-life data is complex, rich and challenging. This section shows how data description ceased to be an automatic process and instead became an exercise in thinking and judgment. The data with which the students were working were "natural", i.e. they had not been manipulated to make them easier for use. This is how it is in real life: surprising, challenging, and unique. So these students worked with a plurality of data and variables out of which they would have to choose the ones that were relevant to their particular problem. Since they had to decide on what to focus, and what to ignore, the situation could not be addressed purely technically and automatically. This kind of practice contrasts with the usual type of exercise which tends to provide students with the relevant data for dealing with a specific problem.

Two especially noteworthy issues which are extremely important in understanding descriptive statistics arise in the study of real-life data: (a) dealing with outliers, and (b) relating to missing values.

### **4.2.1 Dealing with outliers**

It often happens that students at work on realistic cases run into difficulty when they discover that a small number of their values are extreme when compared to the majority of the data. So,

for instance, one of the participants collected data relating to the social status of pupils in her classroom. She gave her pupils a short questionnaire which included, among other questions, the following one: "How many friends do you have in the class?" Most responses indicated between one to six friends. Two children however, wrote: "All the children in the class are my friends – I have 30 friends." An extreme value like 30 obviously affects the data organization as well as the majority of the measures of central tendency and of variation.

This caused a problem that required some considerations. One thing this situation made possible, was to have a look at what actually happens with statistical measures when extreme outliers are included, and what happens if they are excluded from the analysis. What's important is that analysis, here, is not automatic and mechanistic. The problem requires thought and deliberation. As a result the entire learning situation is richer, more sophisticated, and more likely to stimulate the students. It is also worth mentioning that this kind of data invites considerations about the nature and quality of the data collection process and implications concerning validity and reliability of measurement instruments like questionnaires. Students come to understand that such information is meaningful in statistical analysis as it provides crucial background material. They become aware that data do not exist in a vacuum, but that there is a story behind the numbers; students learn that statistical analysis involves developing the "narrative" of the data, "unlocking the stories in the data" ([Garfield & Ben-Zvi, 2007, pp. 19](#)).

#### **4.2.2 Relating to missing values**

Quite often values were missing from the sequence of data that students collected. Here as in real life, students were required to think and decide how to cope with the missing data. For example, the data collected by one student included grade point average of first year college students majoring in the humanities (literature, language, and Bible studies), and the high school matriculation grades of these same students in literature and Bible studies. For some reason, not all data were available for all the respondents. Three of them, for instance, did not get a matriculation grade for literature, and the same was true of Bible studies for another three students. The student who was doing the analysis wanted to calculate the correlation between success in high school and success in college, in the context of the humanities. Here, she hit upon a few questions which complicated the statistical analysis and required special attention rather than automatically applying the "recipe" for calculating correlations. Her first dilemma was whether she should calculate two correlation coefficients, one between grade average during the first year at college and matriculation grade for Bible studies, and one between college grade average and matriculation grade for literature? Second, the student had to cope with the question of missing values, since each time the calculation was done only for the group for which there were data related to the two relevant variables. As a result, the correlation coefficients would have been calculated each time for a slightly different group. The student herself came up with an interesting solution: Assign a matriculation grade to each respondent based on the average of the grades in literature and Bible studies. The correlation with the grade average of year one at college, then, would be calculated with respect to the average grade in the two matriculation subjects. Thus the student solved the two problems she encountered very elegantly. She decided to run one correlation coefficient instead of two, and she also coped with the missing values obstacle.

These are only two instances of how authentic data collection creates conditions that challenge us to deal with realistic, interesting, and stimulating tasks which require thought, creativity and a clarification of the learned material. Usually, textbooks don't provide such interesting situations. From the point of view of constructivism, it should be pointed out that what matters is not finding an unambiguous solution to a question, but the process of deliberating, the personal involvement in the active process of finding a solution, supported by conceptual clarification, logical reasoning and statistical thinking.

Teaching and evaluation that include this type of analysis prepare students for real life situations rather than keeping them in a sterile bubble characteristic of educational institutions.

### **4.3 Relevance and motivation**

Since the students had been practicing the statistical procedures in real-life situations which resemble those of actual research, they were challenged and experienced the relevance of the subject matter. As a result, the students showed interest and enthusiasm and asked countless questions that arose in doing the assignments. Conversations with teachers and teacher assistants revealed that the homework assignments came alive and raised students' motivation to deal with the data. Students were in constant touch with their instructors and asked for further suggestions. Often, students came up with two possible solutions and asked for their instructor's opinion about which to prefer. Below are some illustrations.

One of the students looked into the issue of reading habits of pupils in her class. She discovered that most of her pupils read very little, though there were a few who read quite a bit. This disparity drew her interest and, based on her familiarity with the children, she hypothesized that one explanation for the fact that some were "prolific readers" might be that they lived at a greater distance from the school than the others. According to this theory, living at a distance made it more difficult for them to meet with their classmates after school. Then the student decided to interview *all* the pupils, thus, introducing an additional variable into her study: leisure time spent with friends. This student put the extra effort into her work not because of the statistics course, but because of the relevance of the subject to her life and work.

Another student, whose work yielded a correlation coefficient that was very different from the one he had expected, went to the research literature in order to understand why.

On the whole, there were quite a few students who did not stop at doing the standard statistical procedures, but went further and related them to background material and made an effort to make sense of their outcomes. The context of the data allowed them not only to understand how to organize and to analyze data but also why they should be analyzed. Such expressions of interest and involvement occurred several times in the process of learning, as teachers as well as teacher assistants reported.

### **4.4 Interconnectedness and transfer**

Statistics teaching at the college was intended to enable students to apply what they were learning, with the aim that they should know how to use statistical tools in their continued

studies and in their professional lives. In the groups under study, students were in the position to apply what they had learned in situations that resembled those they might encounter in the future. They had a concrete experience of utilization, of attempting to act the way researchers do when they process real-life data. After collecting data related to a certain question, they initiated a series of staged activities to discover what these data revealed. They first organized the data in a certain way, and then looked at the resulting picture. Often, after this first stage, they decided to shift to another mode of representation, adding another, more appropriate, measure or calculation until they reached a reasonable and coherent picture. In the course of their investigations, their knowledge developed and became more profound, resulting in a meaningful process of learning. They revisited the same data, again and again. Information in one dimension gave support and clarified, and sometimes raised more questions, regarding information in another dimension. Gradually it became possible to put something into words. This kind of thinking, which is sensitive to the situation under study, encourages the intellectual flexibility that is necessary for efficient implementation of statistical procedures and ideas. As a consequence students are more likely to demonstrate improved ability to transfer related knowledge to other relevant situations. Following are two illustrations of how this method of contextual learning enhances transfer.

The first example shows how important the "whole picture" is to our pursuit of conceptual understanding. When students did their homework assignments they repeatedly revisited the same data set for different purposes and carried out different statistical procedures. First, they calculated frequency distributions of variables and groups and compared them. Subsequently, they learned about measures of central tendency and calculated them for the data set. This was followed by learning about measures of variation and calculating them. Soon it was necessary to combine ideas and to generalize, so that it would be possible to see what could be learned about the various groups from what had been done so far. This, for instance, was how students learned that if they wanted to calculate central tendency and variation measures they would have to revisit the raw data, rather than calculate them from frequency distributions with class intervals.

The students in these study groups were more aware than their peers in the regular groups, that familiarity with the data allowed them to draw general conclusions over and beyond the specific measures, by linking information gleaned from observing frequency distributions together with that resulting from measures of central tendency and variation.

Such assignments could also be given to groups studying with traditional methods, but usually this is not done. A look at popular statistics textbooks in tertiary education and at the end-of-chapter exercises they provide reveals their isolated, sterile nature. By contrast, when a student persistently revisits the same data, there is an inherent tendency to generalize and develop a heightened awareness of the whole picture.

The next example is even more interesting because it shows how a student's familiarity with and proximity to the situation under study, and her repeated revisiting of the data for different purposes, actually helped her to raise questions and to gain a better understanding of the whole situation, than when she had studied each chapter separately and in isolation.

One of the participating students, a school-teacher, had collected data in her class. Among other things, she collected data about her students' achievement in English, when they were in fifth,

and then in sixth grade. In the first stages of the analysis she compared the children's achievements in these two consecutive years. Since this school-teacher happened to be the English teacher in sixth grade, she was, of course, delighted to find that her students' achievement had improved. The rise in the average grade was clearly reflected in the graphic and tabular representations. Several weeks later, when the college statistics course was covering correlation coefficients, the student became curious about whether there was a correlation between her pupils' achievements in fifth grade and in sixth grade. To her amazement, when she calculated the correlation coefficient it turned out to be high ( $r = 0.74$ ). Moreover, her interpretation of this outcome was well-grounded: **"My conclusion is that usually the pupils who did well in fifth grade also did well in sixth grade, while those who were weak in English in fifth grade, stayed so in sixth."** Still, the student wondered how this was possible: **"Didn't I find in earlier exercises that *all* the pupils had improved?"** Such reflection is not likely to occur when doing conventional course assignments based on "end-of-chapter exercises". It was only because the student went back to her own data that this misconception surfaced as she forged the link between previous and more recently acquired knowledge. She had not figured out that while all pupils may improve, a high correlation coefficient can still be found between the test marks in fifth and sixth grades.

This is the linking that creates "big ideas" in relation to the learned material and which will, eventually enhance conceptual change and allow for transfer of learning. It is the context and other "background" information that form the scaffolding for understanding statistical concepts and principles.

#### **4.5 Learner empowerment**

This type of teaching which involves students in the learning process requires a more active type of learning where the students are led to interpret the material they study. As reported previously, participating students were encouraged to ask questions and focus on difficulties. Obviously, more questions arose when students were exploring data they had collected themselves than with conventional modes of teaching. They also tended to express their difficulties in analyzing the data and often became quite frustrated. In part this was due to their involvement, but it also was the result of the *messy* nature of the data. The frequent dialogues between teacher and students increased student involvement even further and caused the learning process to become more precisely adjusted to students' needs and hence, more meaningful to them. Moreover, such dialogues offer teachers and students opportunities to give and get feedback. At times an entire class session was devoted to the data presented by one student, with the teacher taking the opportunity to teach the whole class some topic or some aspect of the subject matter that was highlighted by a student's question.

This type of dialogue, where teachers could not always be ready with solutions they had worked out beforehand (as is the case in conventional classes), was empowering for the student. Often, such situations demanded that teachers reveal their own ways of thinking, be more flexible and show how they coped with unanticipated issues.

Below are two illustrations of issues that arose through students' initiative and which we can reasonably relate to their being exposed to real life data analyses. The first illustration addresses frequency distributions of nominal variables, and the second relates to drawing conclusions from authentic distributions. They demonstrate how dealing with authentic data led students to be in a position of influence and control vis-à-vis the nature of their learning and evaluation and thus to their empowerment.

#### 4.5.1 Grouping data in nominal variables

When teaching the subject of grouping of data in class intervals, we are usually dealing with interval, or at least ordinal, variables. Sometimes, teachers explain why it is not suitable to create class intervals when the variable is nominal. Usually, however, little attention is paid to this point and surely many students do not grasp the significance of clearly describing the nature of the variable being dealt with. It is well known that even when the teacher explains a certain issue during the lesson, we cannot be sure that the students have actually grasped its full meaning. This example is a good case in point. When the students were asked to formulate a question requiring an answer in terms of grouping of data in class intervals, it turned out that several students chose to group nominal variables. When solving the exercise, however, they treated the nominal variable as an interval variable. So, for instance, when dealing with the variable *play area in kindergarten*, one student examined to which play area in kindergarten children choose to go during break time. This is how she labeled the variable values:

1. *Dolls' corner*
2. *Pet animals*
3. *Carpentry*
4. *Book corner*
- .
- .
- .
14. *Doctor's corner*

When the student saw that the variable had many values, she decided to aggregate them into classes. However, she did this by referring to the *code number* of the variable. So while the student was able to state that the variable was nominal, when she was required to further deal with it, she acted as though the arbitrary code number had quantitative significance. This problem confronted the teacher with the need to explicitly discuss the issue of grouping nominal variables – which of course needs to be carried out in reference to the category content and not to its arbitrary numbering. This type of grouping is essentially unlike grouping of exam grades for example, where the variables are interval or ordinal.

Another frequent phenomenon basically similar to the one above was observed in students' work when they produced graphic descriptions of frequency distributions of nominal variables, where the code numbers are meaningless – yet the students marked the variable values on the X axis as fully-fledged values. Subsequently, students even drew conclusions on the basis of these "values", e.g.: "This is a distribution that is negatively skewed".

#### **4.5.2 Drawing conclusions on the basis of authentic distributions**

The conventional type of exercise that appears in many statistics textbooks uses data that tend to illustrate in an obvious and artificial way what the exercise is meant to teach. This may have its advantages. But when students come to do independent research with real-life data, they soon discover that what is required is very different from what they've studied. Of course, the work in the study groups described in this paper puts students in a different position.

Questions like the following often arose in these groups: How do we sum up the data when they are not really unambiguous and clear? How do we draw conclusions on such a basis? What do we write down? Here, too, outcome is less important than process. There will always be different ways to organize and study data. What really matters is the thinking itself, the work with the data, and coping with the need to understand their meaning.

There were additional occasions when issues arose, in class, as a result of students' needs. Some of them have been described above to illustrate advantages of using real-life data in assignments: missing data, extreme values, and generalization and reflection based on information acquired in several statistical procedures. It should be clear that some of these issues arise in regular teaching sessions in the most conventional of teaching environments. What we wish to emphasize here is that in the study groups described in this paper, in-depth discussion and reflection on topics which derived from the analysis of the real-life data were so prominent that they assigned a new dimension to teaching and learning alike.

Another interesting issue that appeared often in the exercises of students of these groups, and thus demanded a response from the teacher, was the occurrence of non-linear relationships between variables. Often, when students asked questions about the relationship between variables, and when they drew scatter plots of two variables, there was a tendency towards a non-linear relationship. Again, this situation arising from students' own needs, offered the teacher a good opportunity to discuss and illustrate the fact that though a Pearson correlation coefficient (something they had been studying in some depth) works as a measure for a linear relationship, we are often actually presented with non-linear patterns.

To sum up, students who studied with a teaching-evaluation method that involved dealing with real-life data had an opportunity, even if on a small scale, to experience some of the joy and pleasure of data investigation. This method, which used real-life conditions as the basis for assignments in descriptive statistics, helped the students understand the purpose of data analysis. Moreover, these students were given the opportunity to discover that data description can not be covered by one set of rules. Rather, analysis of data requires complex action that is based on conceptual flexibility, an ability to integrate study material, and creative thinking. To a certain extent, students in these groups could function like researchers, and hence like knowledge producers rather than knowledge consumers.

### **5. Discussion**

This article describes an experience with a teaching method, which incorporated alternative assessment in descriptive statistics classes. A look at the research literature devoted to the

teaching of statistics in the last 20 years reflects much disappointment, especially in relation to students who take statistics as a compulsory service course. Although alternative and diverse ways of teaching have been emerging, the traditional lecture format and delivery of information model remains the mainstay of many statistics courses in tertiary education ([Chance, delMas & Garfield, 2004](#); [Garfield & Ben-Zvi, 2007](#); [Groth, 2007](#); [Moore, 1997](#)). The literature is replete with comments about students who never attain a reasonable grasp of the most basic concepts, and who don't have the knowledge that allows them to implement what they have studied. Many of the acquired concepts remain abstract and unrelated to relevant, practical application (cf., [Coleman, 1999](#); [Drew, 1997](#); [Broers & Imbos, 2005](#); [Garfield & Ahlgren, 1988](#); [Herman, Notzer, Libman, Braunstein, & Steinberg, 2007](#); [Jolliffe, 1976](#); [Kalton, 1973](#); [Shaughnessy, 1992](#); [Singer & Willett, 1990](#)). Traditional methods of statistics teaching have come under serious criticism because of their failure to help students achieve sufficient in-depth understanding of concepts and principles so as to be able to use them in new situations. Traditional teaching, moreover, has also been accused of causing students to dislike statistics, to assume that statistics is a particularly difficult mathematical subject that is superfluous and irrelevant. Even more striking is that at institutions for higher education, which define themselves as knowledge-creating communities, the dominant teaching approach is still transmission and transfer of knowledge ([Mandl, Gruber, & Renkl, 1996](#)).

Referring to constructivist perspectives, this article suggests a look at the potential of inculcating alternative teaching methods that encourage students to take a more active role in their own learning and participate in the process of assessing what they have learned. Our decision to introduce alternative assessment in the form of exercises that are based on real-life data collected by the students was based on the view that learning is essentially a journey of personal development. Such an approach seems even more valid when we are talking about applied academic studies such as statistics, whose very objective is to enable students to conduct independent inquiry through intelligent use of statistical tools. Such tools will also serve them in their future work either as teachers or as students.

Concluding, in brief, from the experience presented above, we believe that students, who had the opportunity to practice the material they had learned in the lecture hall on real-life data which they themselves had collected, almost certainly experienced some of the pleasure of discovery that comes with data investigation. Furthermore, there is reason to assume that such a teaching approach will encourage students to take greater interest in statistics and might prompt them to take advanced statistical courses.

From feedback provided by students as part of the teaching process, it was clear that their investment in the learning process was considerable. They reported that they were "using their minds" trying to understand the topic in depth. Students repeatedly stated that "in this course, we feel that we have learned something that we can use". Students also remarked more than once that "they had learned something which was not just 'for the exam'". The fact that the material was close to their own experience and that the statistical knowledge they were supposed to master was embedded in the practical problems they were called upon to confront, helped to convince them that "statistics was important for the future".

In the final feedback session of the course, many students remarked that they would register for a more advanced course in statistics, even though they were not required to do so. It would also seem relevant to point out that the average grade of the students in this course, on the basis of a similar final exam, was higher by more than 0.5 standard deviation compared to two previous cohorts. This finding certainly hints that the teaching method we have described has the potential to enhance learning and that we should continue to investigate it in depth.

Naturally, this is an impression based on informal information that demands empirical validation.

This article also illustrated how this teaching-evaluation method enabled students to realize that there is no single set of procedures that can be used to describe and analyze all data sets. Imparting meaning to sets of data is a complex activity which involves conceptual flexibility, integration of all the procedures that one has learned, and creative reasoning. The use of performance assessment enabled the course participants to function to a certain extent as true researchers, and hence as knowledge producers rather than knowledge consumers. It is important, however, to understand the role of teachers in this process. Students aren't forced to tackle advanced aspects of learning single-handedly. The involvement of the teachers in their students' learning process, as guides and supervisors, is crucial – advising students, helping them in avoiding pitfalls or overcoming them, providing students with the necessary tools to cope with what these demanding learning methods require.

This article looks at the potential of incorporating alternative assessment components to improve instructional practices and hence to enhance meaningful statistical understanding. Other important aspects of using authentic assessment, like grading students' assignments or assessing their outcomes, are beyond the scope of this article. Yet, it seemed that, in spite of the considerable effort and investment required, students were involved, conducted the exercises effectively, and usually expressed satisfaction with this learning method. Teachers and teacher assistants reported that students frequently commented that they had personally developed and acquired knowledge they thought they would be able to utilize in the future. These are of course subjective impressions which cannot serve as scientific proof of the success of this teaching-evaluation method. It should be remembered, however, that constructivism maintains that conceptual change and personal development are not exclusively the outcome of cognitive factors. Beliefs, expectations, and subjective perceptions, too, play a crucial role in impacting human development and growth.

Another issue worth mentioning is the question of cooperation on the part of teachers in higher education in changing attitudes and habits as far as teaching and assessment practices are concerned. Teachers play a crucial role in successfully revising and implementing teaching methods. It is common knowledge that teachers in higher education feel strongly responsible for the curriculum, the rigid syllabus of their course, and finally examination and assessment of learning outcomes. They usually insist on sticking to timetables and worry about losing control in class ([Biggs, 1996](#); [Good, Clark, & Clark, 1997](#)). Experts in their disciplines but often having limited training as teachers, they have developed their own working methods, tests, materials, and examples ([Biggs, 1996](#); [Good et al., 1997](#)). Those among them with more experience are unable, and often unwilling, to reconsider their teaching and evaluation methods ([Biggs, 1996](#); [Good et al., 1997](#); [Maurer, Bell, Woods, & Allen, 2006](#); [Watt, 2005](#)). This is, to some extent,

true as well for the teachers who worked with the study groups described in this study. All three of them were experienced teachers with their own teaching habits, practices, lesson plans, and stores of examples, illustrations, and evaluation tools.

Including an alternative assessment component affected class sessions, with the teachers and trainers having to deal with questions and issues arising from the students' work on the exercises. This required improvisation and flexibility. Teachers reported that the experience was challenging and stimulating but also extremely demanding. Indeed, one of the conclusions that can be drawn from this study is that if teachers are to "take off" with alternative methods of teaching statistics and discover their potential, they will have to adjust their perceptions, beliefs, work methods, and their readiness to invest in teaching improvement ([Brown & Palincsar, 1989](#); [Eisner, 1999](#); [Fullan, 1985, 1993](#); [Volet, McGill, & Pears, 1995](#); [Watt, 2005](#)). This issue, which has recently received more attention as a result of increasing awareness of the quality of teaching in tertiary institutions, is especially problematic in the context statistics education ([Biggs, 1996](#); [Broers & Imbos, 2005](#); [Chang, 2000](#); [Ding & Sherman, 2006](#); [Volet et al., 1995](#); [Wollert & West, 2000](#)).

Finally, there is the question of learning outcomes. Are constructivist teaching-evaluation methods a success story? Are they more effective than their traditional counterparts? Are the effort and investment worth our while? The results of many recent studies are contradictory and unconvincing ([Cobb & Jackson, 2008](#); [Eisner, 1999](#); [Laroche, 2007](#); [Maurer et al., 2006](#); [Watt, 2005](#)). These methods have very enthusiastic supporters but they have also aroused much opposition and disappointment. It can however be added that, like in other education-related issues, this one too has a profoundly ideological aspect. Many would argue that a constructivist approach is democratic and egalitarian and that the difficulty in proving its effectiveness is of less importance.

The experience described in this article taught us a great deal about student learning, about ways of thinking and perceiving concepts and ideas in statistics. It seems to us that this experience improved participants' teaching and their students' learning processes. We therefore decided to continue our research into the effectiveness of constructivist teaching methods in descriptive statistics with special emphasis on methodological rigor and controls. Preliminary results concerning this research seem very promising and indicate a significant advantage of the teaching method discussed in this paper ([Libman, 2009](#)).

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