FOSTERING STUDENTS' STATISTICAL REASONING, SELF-EFFICACY, AND ATTITUDES: FINDINGS FROM A COMPREHENSIVELY REFORMED UNDERGRADUATE STATISTICS COURSE

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This study investigated to which degree a reform-based introductory statistics course improved its participants' statistical reasoning ability, their statistics self-efficacy, and their attitude toward the usefulness of statistics. In addition, it examined whether the learning outcomes differed with respect to the students' mathematical background, their class attendance, and their perceived teacher support. Ninety-six first year university students (97% female, mean age 19) participating in an introductory statistics course were assessed both at the beginning and at the end of the course. The results showed that the students' statistical reasoning ability and statistics self-efficacy increased significantly during the course. However, no significant changes were observed in their attitude toward the usefulness of statistics. The improvements in the students' statistical reasoning ability and statistics self-efficacy were regardless of their mathematical background, course attendance, and perceived teacher support. In this paper we present the results of this research study and discuss their implications for instruction, after which we will make some suggestions for further research.

INTRODUCTION

Over the past few decades, a widespread reform movement has emerged to transform the teaching of statistics at the tertiary level. As a result, many instructors have aligned their courses with the recommendations of this reform, which are aimed at developing students' statistical reasoning ability as well as improving their attitude toward and self-beliefs about statistics (Garfield, 2001). However, the question whether these recommendations have indeed led to the attainment of these aims has as yet received only little attention. Some previous studies reported improvements of the level of students' reasoning ability (e.g., delMas, Garfield, Ooms & Chance, 2007) or attitudes (e.g., Schau, 2000) over a reformed instruction. Other research has shown no statistically significant changes in their reasoning skills (e.g., Hirsch & O'Donnell, 2001) or self-beliefs (e.g., Green, 1993) despite good grades in the courses. Most of these previous studies have merely examined the changes in particular types of statistical reasoning ability, for example reasoning about sampling distribution (e.g., delMas, Garfield & Chance, 1999), reasoning about standard deviation (delMas & Lui, 2005), reasoning about bivariate data (Zieffler, 2006) or changes in self-beliefs about statistics (Finney & Schraw, 2003). The innovative instructions in these studies usually pertained to one particular aspect of the reform recommendations, for example application of a specific active learning method or technology tool, such as cooperative learning (Magel, 1998) or simulation programs (delMas et al., 1999).

This study investigates whether courses in which the synergic aspects of the reform recommendations are combined actually improve students' cognitive and affective learning skills, and if so, whether there are any additional factors which have an influence. We investigated possible changes in students' statistical reasoning ability, their attitudes toward the usefulness of statistics, and their statistics self-efficacy. Further, we studied whether or not the changes in these interdependent learning outcomes varied across students in terms of their mathematical background, their perceived teacher support, and the frequency with which they attended the course.

METHOD

The participants were 96 (97 % female, average age 19, ranging from 17 to 25) first year pedagogical science students who attended an introductory undergraduate descriptive statistics course. The course was a trimester course and involved 12 lecture (12 x 2 hrs) and 4 small-group (4 x 2 hrs) sessions. The general goal of the course was to develop students' conceptual understanding of various topics in the course and thereby promote their self-efficacy and attitudes toward statistics. To this end, it was organized around the Guidelines for Assessment and Instruction in

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Statistics Education (GAISE, 2005) in terms of content, pedagogy, technological use and assessment.

Content

The text-book used in the course was *Introduction to the practice of Statistics 6th edition,* by David S. Moore, George P. McCabe and Bruce Craig (2009). The first four chapters of the book, topics of the distribution of data, the relationships between variables, data production, and introductory probability directed to the study of randomness were covered. Unlike many other introductory statistics books, the book focuses on promoting statistical understanding and reasoning ability. A previous edition of it has been labeled as a reform based text-book (Garfield, 2001), which obviously pertains to this one.

Pedagogics

The lectures were mixed lectures which involved teacher led questions and discussions. About a third of the time was used for discussions. The small-group (an average of 10 students) sessions were directed at actively practising the subject matter. Usually, the small-group work consisted of assignments on one or more given data sets. These assignments were structured in such a way that the topic of the practical, also discussed in the previous lecture, was dealt with systematically. A PhD student guided these meetings, usually walking around and answering questions, giving feedback on the students' remarks, and summarizing of the most important topics covered.

Technological support

The lectures were presented by means of PowerPoint. The Power Point slides were published on a Blackboard system (called Nestor) prior to the lecture in order to give students the opportunity to study them beforehand. Via a digital discussion board, to which the teacher had access as well, the students could discuss statistical problems which they had encountered in the course. During the small-group sessions SPSS was introduced to analyze data sets on a very basic level, as well as a program called StatPlay. StatPlay is an interactive program through which students can learn some key introductory statistical concepts.

Feedback

Students were provided with feedbacks/answers for questions during the lectures, the small-group works, and via e-mail. Per enrolled student, there was on average one question asked via e-mail. If a question was asked more than once, the question and the answer were also presented on Nestor. Furthermore, three previous examinations were published on Nestor, as well as answers of model questions in the examinations. In the text-book, many exercises were presented, and for the odd numbered questions, the answers were given.

Measures and Procedures

Participants were assessed for their statistical reasoning ability, statistics self-efficacy, and attitudes towards the usefulness of statistics using scales developed based on preexisting instruments both at the beginning and at the end of the course. Their perceived teacher support, on the other hand, was assessed only at the end of the course. This was because in our opinion students are only able to form a balanced perception of their teacher at the end of a course. All questionnaires were arranged in a booklet in an order where the self-report scales preceded the reasoning test. The questionnaire was administered in a controlled classroom setting, and it took between 25 and 35 minutes to complete. Participants' mathematical background refers to students' reported secondary school mathematics levels and scores. Course attendance was registered for each lecture and each small-group session. Eighty percent of the students attended more than 70% of the sessions, while the rest attended fewer classes than that.

RESULTS

Changes in Reasoning, Self-efficacy, and Attitudes

A repeated measure t-test was carried out to examine the extent to which students' statistical reasoning ability, their attitude toward statistics, and their statistics self-efficacy changed during the reformed introductory undergraduate statistics course (See Table 1). The results showed that there was a statistically significant mean increase in statistical reasoning ability and statistics self-efficacy. The mean increase in statistical reasoning ability was 1.60 (99% CI: .97 to 2.24; eta squared = .32). This improvement was consistent across all content areas measured in the test. The pre-to-post course change in statistics self-efficacy was .23 (99% CI: .13 to .34; eta squared = .27). On the other hand, no significant change was detected in the students' attitude toward the usefulness of statistics (mean difference = -.05, 99% CI: -.12 to .01; eta squared = .02).

Table 1. T-tests for Differences in Variables Before and After the Course

Variables	Pretest		Post-test		Change		99% CI
	M	SD	M	SD	M	SD	
Reasoning	9.07	2.19	10.68	2.31	1.60	2.38	[.97, 2.24]
Descriptive	4.88	1.28	5.38	1.33	.50	1.26	[.16, .84]
Graphical	1.58	0.78	1.98	0.86	.40	.94	[.15, .65]
Probability	2.64	1.15	3.34	0.89	.69	1.15	[.39, 1.00]
Efficacy	2.89	.37	3.07	.44	.23	.39	[.13, .34]
Attitude	2.89	.36	2.48	.34	-.05	.24	[-.12, .01]

Note. The scores for statistical reasoning ability could range from 0 to 15 correct questions. For statistics self-efficacy and attitude toward statistics, the average scores could range from 1 (strongly disagree) to 4 (strongly agree). Change = post-test - pretest. N = 96.

Changes across the Levels of Secondary School Mathematics

A two-way repeated ANOVA measure (mixed between- within-subject analysis of variance) was conducted to assess whether or not the pre-to-post course changes in the learning outcomes studied varied across the participants' secondary school mathematics levels. The results revealed no significant interaction effects between the secondary school mathematics levels and the pre-to-post course changes with respect to statistical reasoning ability [Wilks' Lambda = .98, F (2 , 93) = 1.03, *p* = .36, partial eta squared = .02]. This also applied to statistics self-efficacy [Wilks' Lambda = .99, F (2, 90) = 0.31, *p* = .74, partial eta squared = .01], and attitude toward the usefulness of statistics [Wilks' Lambda = .99, F (2, 90) = .48, *p* = .62, partial eta squared = .01].

Changes in Relation to Secondary School Mathematics Score, Course Attendance, and Perceived Teacher Support

A partial correlation analysis was performed to assess whether or not the changes in the learning outcomes were related to the students' secondary school mathematics scores, their course attendance rate, and their perceived teacher support. The analysis was conducted by correlating the change scores of the learning outcomes with one of these moderator variables (by subtracting each of the pre-course scores from the post-course scores), while controlling for the remaining other variables, including secondary school mathematics level. The result revealed that the changes in all three learning outcomes were not significantly related to the students' secondary school mathematics scores, perceived teacher support, and course attendance rate.

CONCLUSION AND IMPLICATIONS

The findings of this study support the hypothesis that an introductory statistics course which includes a large spectrum of the recommended reform measures can improve students' statistical reasoning ability as well as their confidence in performing statistics-related tasks. These improvements seem to occur regardless of their mathematical background. The finding of an increase in statistical reasoning ability by reform-oriented education is in line with other studies (e.g., delMas et al., 1999), as well as the improvement of students' confidence in their capability to perform statistical tasks (e.g., Finney & Schraw, 2003), and the absence of significant change in attitudes (e.g., Green, 1993). However, the mean increase can not be absolute guarantee for the improvement of a student's level of skill in statistical reasoning or for the elimination of his/her misconceptions about statistics. Furthermore, although this study provides important insights into the attainment of cognitive and affective learning objectives through reform-oriented instruction, there are limitations that should be acknowledged. First, the lack of a control group in this study makes it impossible to draw definitive causal conclusions. Second, the participants in this study were predominantly females, and generalizing the results to males may be tenuous.

Nevertheless, the findings of this study do have implications for practice and for research. The major practical implication for statistics teachers is the need to consider the introduction of an integrated and well-informed change in all major instructional components of their courses (including content, pedagogy, the use of technological tools, and assessment) in order to impact their students' learning positively. This will not only lead to a better realization of the learning outcomes desired, but will also enable teachers to address the needs of all learners with their different abilities, learning styles, and backgrounds. In addition, one of the statistics teachers' tasks is to lay the motivational foundation of the students' attitudes toward and beliefs about statistics. As this study has shown, comprehensive instructional reform can be a means to influence students' self-confidence with respect to statistics.

With respect to the implication for further research, the present study suggests the use of experimental design. Especially the impact of classroom contexts on the development of students' statistical reasoning and thinking abilities and on the improvement of their attitude and beliefs require further study. In addition, it would be useful to focus on the interplay between the cognitive and non-cognitive course outcomes in relation to course grades. Finally, we measured 'statistics self-efficacy' by using indicators associated with specific statistical personalized tasks. However, we did not use these indicators when measuring 'attitude toward the usefulness of statistics.' Even if further empirical study is first required on this issue, it is worthy pointing out the appropriateness of using personalized and specific items when measuring components of affect behavior.

REFERENCES

delMas, R. C., Garfield, J., & Chance, B. L. (1999). A model of classroom research in action: Developing simulation activities to improve students' statistical reasoning. *Journal of Statistics Education*, *7*(3).

delMas, R., Garfield, J., Ooms, A., & Chance, B. (2007). Assessing students' conceptual understanding after a first course in statistics. *Statistics Education Research Journal, 6*(2), 28-58.

delMas, R. C., & Liu, Y. (2005). Exploring students' conceptions of the standard deviation. *Statistics Education Research Journal*, *4*(1), 55-82.

Finney, S. J., & Schraw, G. (2003). Self-efficacy beliefs in college statistics courses. *Contemporary Educational Psychology*, *28*, 161-186.

GAISE (2005). Guidelines for assessment and instruction in statistics education (GAISE) college report. The American Statistical Association (ASA). Retrieved on December 4, 2008 from http://www.amstat.org/education/gaise/GAISECollege.htm.

Garfield, J. (2001). Evaluating the impact of educational reform in statistics: A survey of introductory statistics courses. Final Report for NSF Grant REC-9732404.

Green, K. E. (1993, April). Affective, evaluative, and behavioral components of attitudes toward statistics. Paper presented at the *meeting of the American Educational Research Association, Atlanta.*

Hirsch, L. S., & O'Donnell, A. M. (2001). Representativeness in statistical reasoning: Identifying and assessing misconceptions. *Journal of Statistics Education*, *9*(2).

Magel, R. C. (1998). Using cooperative learning in a large introductory statistics class. *Journal of Statistics Education*, *6*(3).

Schau, C. (2000, November). Teaching and learning in statistics courses: Importance of students' attitudes and beliefs. Paper presented to the faculty at Arizona State University.

Zieffler, A. (2006). A longitudinal investigation of the development of college students' reasoning about bivariate data during an introductory statistics course. Unpublished doctoral dissertation, University of Minnesota, Minnesota.