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# The Effects of Metacognition-Oriented Instruction on Statistics Education for Preservice Teachers

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**Abstract:** *The purpose of this study aims to investigate the effects of IMPROVE (Introducing the new concepts, Meta-cognitive questioning, Practicing, Reviewing, Obtaining mastery, Verification, Enrichment and remedial) instruction on university students' statistics achievement and attitude. IMPROVE is the state-of-the-art and metacognition-oriented instruction which is to enhance reasoning by training students to use a series of self-addressed metacognitive questions. Some literatures have confirmed the effects of IMPROVE method on achievement and affect. However, little is known about its effects on university statistics instruction. This study adopts qusi-experimental design, which consists of control group and experimental group, to compare the traditional instruction method and IMPROVE instruction. Results show that these two groups perform the same causal reasoning when they are on the baseline. After both of these two groups participate one semester of statistics course, results show the experimental group has higher statistics achievement than that of control group. Similarly, experimental group also has higher score in certain dimensions of statistics attitude than that of control group. These findings support that the IMPROVE method has positive effects on university students' statistics achievement and attitude. Based on the conclusions, some recommendations and suggestions for future research are discussed.*

**Keywords:** metacognitive instruction, regulation of metacognition, statistics achievement, statistic attitude

## 1. Introduction

In the era of "Big Data", statistics is one branch of applied mathematics that involves data collection, description, analysis, and inference of conclusions from data analysis. Since statistics is so important in many disciplines, the emergence of the reform movement in statistics education has influenced the method of statistics instruction. Innovation of statics education aims to promote students' achievement and affect so that students could apply statistics in their career (Spence, Bailey, & Sharp, 2017).

Scaffolding and metacognition are important factors for learning and instruction. With regard to instruction, the role of the teacher and peer are the progressive relocation of scaffolding agency to help learners take control of their own learning which is metacognition to manage their own knowledge (Holton, & Clarke, 2006). Mevarech and Kramarski (1997) consider three interdependent components, which are metacognitive activities, peer interaction, and systematic provision of feedback-corrective-enrichment, to help students' learning. They provide metacognition-oriented instruction, which is called IMPROVE. IMPROVE is the acronym of all the teaching steps that constitute the following seven steps. They are (1)

Introducing new concepts; (2) Metacognitive questioning; (3) Practicing; (4) Reviewing and reducing difficulties; (5) Obtaining mastery; (6) Verification, and (7) Enrichment. More and more research indicates IMPROVE has positive effects on students' achievement and attitude (Mevarech, & Kramarski, 2014). However, little is known about its effects in learning statistics for university students. Therefore, it is feasible to adopt IMPROVE in statistics instruction to explore its effects on statistics achievement and statistics attitude.

## 2. Literature Review

### Statistics Education

Nowadays, statistics education is an important issue in higher education. It is because statistics help make decision in accordance to quantitative evidence. Statistics is also widely used for problem solving in many disciplines (Tarmizi, & Bayat, 2010). Therefore, statistics instruction and curriculum in higher education need more reforms so as to improve statistics education. Statistics literacy is the state-of-the-art issue of statistics education. Statistics literacy consists of statistical cognition and affect. Statistics achievement and statistics attitude is the major results of statistics education in higher education (García-Santillán, Venegas-Martinez, & Escalera, 2013). Statistics achievement is the performance of cognition-domain while statistics attitude is the performance of affect-domain. Statistics achievement and statistics attitude are two aspects which intertwine together and influence individual statistics literacy (Hilton, Schau, & Olsen, 2004; Orman, & Sevgi, 2019).

Statistics attitude has well-defined and theoretical foundation. Quite a few literatures indicate statistics attitude influences the learning achievement of statistics (Cashin, & Elmore, 2005; Khavenson, Orel, & Tryakshina, 2012). Previous research has suggested that student attitudes toward statistics have been negative. Important variables related to statistics achievement such as mathematics ability, metacognition and student confidence continue to influence students' statistics achievement (Mills, 2004; Vanhoof, Kuppens, Castro Sotos, Verschaffel, & Onghena, 2011). Implications from the literatures might suggest that the metacognition-oriented instruction for statistics in higher education is prospective (Radmehr, & Drake, 2018; Stanisavljevic, Trajkovic, Marinkovic, Bukumiric, Cirkovic, & Milic, 2014).

### Metacognition-oriented Instruction and application in higher education

Metacognition means the awareness of one's own thought processes and the understanding of the thinking behind them. General speaking, there are major two components of metacognition. They are (1) knowledge about cognition and (2) regulation of cognition. In other words, metacognition is the reflecting on one's own ways of thinking and knowing when and how to use knowledge for problem-solving. Metacognition is considered one essential component of literacy and it regulate one's own learning (Mevarech, & Fan, 2018; Oguz, & Ataseven, 2016; Schoenfeld, 2016).

Since metacognition plays an important role in students' learning and teachers' instruction, metacognition-oriented instruction emphasizes regulation of learning and it is the state-of-the-art in education reform (Bol, Campbell, Perez, & Yen, 2016; Kramarski, & Revach, 2009; Mevarech, & Amrany, 2008). IMPROVE is one branch of metacognition-oriented instruction and there are following seven steps. They are (1) Introducing new concepts; (2) Metacognitive questioning; (3) Practicing; (4) Reviewing and reducing difficulties; (5) Obtaining mastery; (6) Verification, and (7) Enrichment. Mevarech and Fridkin (2006) indicate IMPROVE has positive effects on students' achievement and attitude. Especially, they also show the IMPROVE instruction is suitable in higher education because the cognitive loading of

academic disciplines in higher education is required so that psychological mechanism of metacognition is essential in learning.

## 3. Research Design

This study adopts qusi-experimental design to explore the effects of IMPROVE on students' statistics achievement and attitude. The control group is the university students who enroll in 2019 autumn semester of introductory statistics course and the experimental group is the university students who enroll in 2020 autumn semester of introductory statistics course. Students' major of these two group is mathematics education. Both the students in these two groups are preservice elementary school teachers.

Instruction design of control group is the traditional method which is teacher-centered while experimental group is IMPROVE which is metacognition-oriented instruction. The midterm and final statistics assessment are the measurement of statistics achievement. Survey of Attitudes Toward Statistics (SAT-36) is the assessment to measure students' attitude (Schau, 2003; Schau, Stevens, Dauphinee, & Del Vecchio, 1995). SAT-36 consists of 36 Likert-scale items and there are six dimensions of statistics attitude. They are (1) affect; (2) cognitive competence; (3) value; (4) difficulty; (5) interest and (6) effort.

## 4. Results and Discussions

Based on the purpose of this study, there are three experiments. Owing to the causal reasoning is basic ability in learning statistics, experiment 1 is to compare the difference of causal reasoning for these two groups. Experiment 2 is to compare the effects of statistics achievement. Experiment 3 is to compare the effects of statistics attitude.

### 4.1 Experiment 1: comparison on causal reasoning

In the experiment 1, it is to explore to causal reasoning ability of the two groups. The mean comparison t-test is depicted as the Table 1. It shows that there is no significant mean difference between these two classes. Therefore, these two groups almost have the same causal reasoning ability. In Table 2, it reveals that causal reasoning, midterm statistics assessment and final statistics assessment have significantly positive correlation.

**Table 1: Mean comparison of causal reasoning**

| Group | N | Mean | SD | t |
|---|---|---|---|---|
| 2019 | 49 | 11.61 | 1.56 | $1.04^{n.s.}$ |
| 2020 | 54 | 11.94 | 1.69 | |

$^{n.s.}p \geq .05$

**Table 2: Correlation coefficients among three variables**

| | Causal reasoning | Midterm statistics assessment | Final statistics assessment |
|---|---|---|---|
| **Causal reasoning** | | 0.401*** | 0.414*** |
| **Midterm statistics assessment** | | | 0.711*** |

$*** p < .001$

### 4.2 Experiment 2: comparisons on the mean of statistics assessment

Firstly, this study investigates the effects of IMPROVE instruction on students' midterm statistics assessment performance and one way ANCOVA is adopted. Causal reasoning and midterm statistics assessment are covariate and dependent variables respectively. Statistics test on homogeneity of regression shows F=3.86 (p=0.052) and it satisfies the assumption of homogeneity of regression. As shown in Table 3, the adjusted mean of two groups are 65.87 and 68.30 respectively. There is no significant mean difference between these two groups. Namely, except to the influence of causal reasoning, the performance of midterm statistics assessment of two groups is quite similar.

**Table 3: One way ANCOVA of midterm statistics assessment**

| Source | SS | df | MS | F | Adjusted Mean | |
|---|---|---|---|---|---|---|
| Group | 149.515 | 1 | 149.515 | 0.708 | Control | 65.87 |
| Causal reasoning | 3883.519 | 1 | 3883.519 | 18.389*** | Experimental | 68.30 |
| Error | 21118.977 | 100 | 211.19 | | | |

Secondly, this study continues to investigate the effects of IMPROVE instruction on students' final statistics assessment performance. Midterm statistics assessment is covariate variable and final assessment is dependent variables. In the same way, one way ANCOVA is adopted to analyze the data. Statistics test on homogeneity of regression shows F=0.031 (p=0.861) and it means the assumption of homogeneity of regression is fine. Table 4 depicts the results of one way ANCOVA. The adjusted mean of control group and experimental group are 47.59and 60.80 respectively. There is significant mean difference between these two groups. Furthermore, except to the influence of midterm statistics assessment, it shows IMPROVE instruction could has positive influence on students' final statistics assessment.

**Table 4: One way ANCOVA of final statistics assessment**

| Source | SS | df | MS | F | Adjusted Mean | |
|---|---|---|---|---|---|---|
| Group | 4349.141 | 1 | 4349.141 | 18.959*** | Control | 47.69 |
| Midterm statistics assessment | 24926.016 | 1 | 24926.016 | 108.646*** | Experimental | 60.80 |
| Error | 22942.379 | 100 | 229.424 | | | |

In accordance with the above results, one is concluded that the IMPROVE instruction could promote students' statistics achievement more than the traditional instruction method. In addition, this study also shows that it may take quite long time, such as one semester, so that the IMPROVE instruction could reveal its positive effects.

### 4.3 Experiment 3: comparisons on the mean of statistics attitude

Experiment 3 aims to evaluate and compare the growth of statistics attitude. This study adopts the assessment "Survey of Attitudes Toward Statistics (SATS-36) "and there are six dimensions in term of statistics (Schau, 2003). They are : (1) affect – students' feelings concerning statistics; (2) cognitive competence – students' attitudes about their intellectual knowledge and skills when applied to statistics; (3) value – students' attitudes about the usefulness, relevance, and worth of statistics in personal and professional life; (4) difficulty – students' attitudes about the difficulty of statistics as a subject; (5) interest – students' level of individual interest in statistics; (6) effort – amount of work the student expends to learn statistics. Ramirez, Schau and Emmioglu (2012) indicate the SATS-36 is suitable for young adults and it has acceptable reliability and validity. 5-ponts Likert scale is the scoring of statistics attitude assessment. Point 1 represents "strongly disagree" and point 5 represent " strongly agree". Higher score means highly positive statistics attitude.

In the beginning of semester and at the end of semester, this study carries out the pre-test and post-test of SATS-36 for control group and experimental group respectively. In accordance with each dimension of statistics attitude, means comparisons of statistics attitude between two groups are depicted in Table 5. In terms of the post-test on affect, cognitive competence and difficulty, it shows that there are significant mean difference between control group and experimental group. Besides, experimental group have higher scores than those of control group. The results support the assumptions that IMPROVE could effectively promote students' attitude. Moreover, this study indicates it is only significant respective to affect, cognitive competence and difficulty, not the overall dimensions.

**Table 5: Means comparisons of statistics attitude between two groups**

| Group and t-test | Dimensions with means | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | affect | | cognitive competence | | value | | difficulty | | interest | | effort | |
| | pre-test | post-test | pre-test | post-test | pre-test | post-test | pre-test | post-test | pre-test | post-test | pre-test | post-test |
| **2019 (N=49)** | **3.52** | **2.33** | **3.46** | **2.48** | **3.37** | **3.37** | **3.32** | **2.93** | **3.44** | **3.12** | **3.25** | **3.11** |
| **2020 (N=54)** | **3.29** | **3.24** | **3.24** | **3.30** | **3.16** | **3.19** | **3.19** | **3.40** | **3.20** | **3.28** | **3.14** | **3.28** |
| **t-test** | **-1.34** | **4.38*** ** | **-1.39** | **4.37*** ** | **-1.38** | **-1.17** | **-0.87** | **3.06** ** | **-1.49** | **0.99** | **-0.75** | **1.04** |

## 5. Conclusions and Suggestions

Nowadays, metacognition-oriented instruction on university statistics course is an important approach to improve university statistics education. This study adopts IMPROVE method to investigate its effects on statistics achievement and attitude. Based on the qusi-experimental design of comparison between the traditional instruction method and IMPROVE, the findings indicate the experimental group has higher statistics achievement than that of control group although these two groups have the same causal reasoning when they are on the baseline. In terms of statistics attitude, experimental group also has higher score in affect, cognitive competence and difficulty than that of control group. Future studies could investigate why the IMPROVE could only promote the above three dimensions (Zhao, Wardeska, McGuire, & Cook, 2014). That is, what the psychological mechanism is about the dimension of value, interest and effort should be a prospective issue.

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