ENTHUSING STUDENTS TOWARDS STATISTICAL LITERACY USING TRANSFORMATIVE LEARNING PARADIGM: IMPLEMENTATION AND APPRAISAL

OCAMPO, Shirlee, ARCILLA, Rechel, CO, Frumencio, JUMANGIT, Ryan & DIOKNO, Felipe
Mathematics Department, De La Salle University,
Philippines

Contact email: shirlee.ocampo@dlsu.edu.ph

Abstract

Innovations in statistics education continuously arise in response to fast developing technologies and changing requirements of globalizing society. Hence, there is a need to shift from traditional method of teaching statistics to new paradigms. This paper presents the improvements implemented along with its appraisal in teaching general education statistics courses using the traditional transmissive pedagogy and then shifting to transformative learning paradigm. The transmissive pedagogy involves merely lectures and paper-and-pen tests, while the transformative learning paradigm integrates computer-based instructions, Web technologies, authentic assessment, problem-based learning, collaborative inquiry, and use of real-life data. Results showed a significant improvement in understanding statistics for both learning paradigms. However, the data did not provide evidence to indicate differences in the amount of learning between the two paradigms. Classical and Bayesian factor analyses both obtained seven non-intellective factors. The two paradigms differ significantly on five factors indicating that students are enthused towards statistical literacy under the transformative learning framework.

KEYWORDS: statistics education, statistical literacy, transformative learning framework, transmissive pedagogy, exploratory factor analysis; Bayesian factor analysis

INTRODUCTION

Statistics education is a fast evolving discipline, and many innovations in it arise in response to the fast developing technologies and changing requirements of globalizing society. Hence, there is a need to shift from traditional method of teaching statistics to new learning paradigms, like the transformative learning framework.

The paper presents the innovations implemented along with its appraisal in teaching general education (GE) statistics courses using the traditional transmissive pedagogy and then shifting to transformative learning paradigm. Specifically, the paper enumerates the improvements incorporated in the course syllabus, instructions, learning processes, materials and environment. The results of the appraisal which include the comparisons of intellective factors and non-intellective factors on learning beliefs and practices under the two pedagogical frameworks are also discussed.

TRANSFORMATIVE LEARNING PARADIGM

Transformative learning (Mesirow, 1997; Cranton, 2002) is a process of getting beyond gaining factual knowledge alone to instead become changed by what one learns in some meaningful way. It involves the transformation of frames of reference (points of view, habits of mind) and critical reflection on how we come to know to develop independent responsible thinking for lifelong learning.

With the end goal of grooming students for lifelong learning, transformative learning framework aims to expand learners' critical and creative thinking by enabling them to generate knowledge from various sources of information, and developing their inquiry, research, synthesis and presentation skills as well as their ability to engage in meta-cognition, self-evaluation and independent learning. Unlike the transmissive pedagogy which assumes that statistics is a content area that includes concepts and procedures that should be "transmitted" from expert systems of knowledge, such as teachers and textbooks, to students, adhering mainly to lecture

format and paper-and-pen tests, transformative learning framework views statistics as an area of inquiry which embodies ways of posing, inquiring, and solving real-life problems developing within the students critical, creative, and reflective thinking, with teachers acting as facilitators of the learning processes using authentic assessment.

Bernardo (2010) provided detailed contrasts between transmissive and transformative learning pedagogical frameworks (Table 1).

Table 1: Contrasts between Transmission and Transformative Learning Pedagogical Systems

Pedagogical Frameworks	
Transmission	Transformation
Perspective on Knowledge Acquisition	
• Knowledge is a set of information waiting to be acquired by student from teachers.	• Knowledge does not exist as a given truth before the learning process. • Students develop knowledge as a result of their inquiry, action or experimentation.
The Work of the Teacher	
• Teacher works as content expert and positions him or her as the primary or only source of knowledge. • The teacher organizes and delivers information and produces and expects students to throw back the given ideas.	• Teacher works with the students' questions about a particular topic. • The teacher facilitates the students' identification of questions and develops with them a plan for answering their questions. • While the teacher's own expertise remains a valuable resource, the teacher also employs a wide variety of resources and interventions to help students understand the questions they need to ask and change or deepen their own prior knowledge. • The teacher challenges students to uncover facts and concepts in interdisciplinary contexts and build knowledge by observing, hypothesizing, experimenting, and discovering. • The teacher prompts students to take risks and explore multiple viewpoints by interacting and collaborating with one another.
Teaching Effectiveness	
• The teacher is deemed effective if he or she is able to present information in a clear and comprehensive way.	• The teacher is considered effective if through such activities, the students are able to accomplish their plan of inquiry and consequently, change or deepen their prior knowledge. With this process of collaborative inquiry, self-assessment and reflection, the students lay the foundations for lifelong learning.
Learning Activities and Learning Environment for Students	
• The lecture format is the preferred and most often used method in class. Students appear passive and are hardly encouraged to question the information.	• For students to succeed, the teacher has to create an atmosphere in the classroom that enhances the students' sense of self-worth, increases their self-confidence and motivation to do their best and affirms their efforts towards self-improvement. • The teacher also has to make the students

	feel that they can discuss or test their ideas and questions freely without fear of being reproached, embarrassed or reprimanded. • With the supportive atmosphere, the teacher is able to encourage critical and creative thinking and the expression of a variety viewpoints and approaches to different issues or problems.
Assessment of Learning	
• Tests require student to provide factual information and prescribed procedures.	• Tests indicate the kind of cognitive growth that has taken place in the students, the changes that have occurred in their conceptual representations, or their ability to solve problems in the field.

Source: Bernardo, A. (2010) The Lasallian Core Curriculum: Development and Early Experiences of the Revised General Education Curriculum of De La Salle University, Philippines. *MALIM SEA Journal of General Studies 11*. 19-34.

INNOVATIONS IN TEACHING STATISTICS

The movement from the traditional transmissive pedagogy to transformative learning paradigm was deemed so as to ensure that the goals of the revised curriculum, especially the higher cognitive objectives, be attained. Such movement entails a total package of pedagogical reforms which include innovations in the course syllabus, instruction, learning environments, and assessment of learning.

Revision of Course Syllabus

Innovations in the course syllabus include articulation of the course objectives as desired results incorporated with expected learners' attributes such as creative and critical thinkers, effective communicators, reflective life-long learners and service-driven citizens; specifications of learning outcomes and learning activities such as actual surveys, analyses of real-life data, inquiry plans, investigations to elicit prior knowledge, seminars/online activities on official statistics, Web and computer activities/simulations, video/movie/article critiques, games of chance, etc.; revision of the course evaluation system so as to include authentic assessment like rubrics; and inclusion of course readings and materials.

Development of Learning Materials

There was a need to develop learning materials to complement such paradigm shift. A module-writing program was initiated. Five modules for teaching statistics under the transformative pedagogical framework were prepared. Module 1 deals with descriptive statistics highlighting collection and organization of real-life data. Module 2 includes probability concepts with real-life applications. Module 3 emphasizes probability and sampling distributions through online simulations. Module 4 focuses on estimation and hypothesis testing using real-life data. Module 5 deals with correlation and simple regression analyses. Each module consists of the following components: materials, time allotment, students' prior ideas, key points for understanding, learning activities, guided discussion sheets, students' inquiry plans, performance tasks/learning outcomes, rubrics/checklists, and references and websites. Seminar-workshops on the implementation of these modules were conducted.

Improvement in Instruction and Learning Environments

Under the transmissive pedagogy, all statistics classes were conducted in classrooms with the lecture format as the most preferred method. Under the transformative learning paradigm, learning environments are designed to include computer-based instructions and Web technologies. A statistics class was reduced from a maximum of 45 students to at most 30 students having one classroom session and one computer session per week. Instruction oftentimes starts with group/individual activities to elicit prior knowledge. Inquiry plans and statistical investigations allow the students to change/deepen their prior knowledge and to build knowledge

by hypothesizing and discovering. Problem-based learning approach is utilized along with collaborative inquiry allowing the students to share multiple approaches, critiques and reflections for various real-life problems, concerns and solutions. Additional experiences are provided by allowing the students to attend seminars on official statistics/poll surveys or to report and critique videos/films on real-life applications of statistical concepts and procedures. Learning outputs/performance tasks which include actual surveys and statistical analyses of real-life data are required as culminating activities of the course.

Inclusion of Authentic Assessment

Along with the shift to transformative learning paradigm, course assessment was revised from absolute standards based solely on paper-and-pen tests to authentic assessment in the form of learning outcomes/outputs, performance tasks, guided discussion sheets, inquiry plans, skills check, computer laboratory work, summative examinations, and learning/on-line activities including those which simply elicit prior knowledge. Performance assessment comes not only in the form of quantitative computations but also in qualitative descriptions of possible outcomes written in rubrics. Other approaches to assessment that require performance in context like portfolios, reflection logs, and checklists are also used. Students are also allowed to reflect and evaluate their learning outcomes and outputs. Hence, assessment of learning takes place even during instruction.

APPRAISAL STUDY

An appraisal study during the first year of implementation of transformative learning pedagogy was conducted using complete enumeration method. The entire population of students taking GE statistics, 82 under the transmissive pedagogy and 318 under transformative learning paradigm was included in the study.

Methodology

Questionnaires on pre/post tests and non-intellective factors were revised after conducting an initial study. The revised pre/post test questionnaire included 35 questions to asses the cognitive learning: 3 items on knowledge, 5 items on comprehension, 10 items on application, 9 items on analysis, and 8 items on synthesis and evaluation. The revised questionnaire on non-intellective factors included 50 items using a seven-point Likert scale. The same sets of revised questionnaires on pre/post tests and non-intellective factors were administered to all GE statistics students under the two paradigms.

Paired comparison t-tests, parametric independent statistical t-tests, and analysis of covariance were employed to evaluate and compare intellective factors. Exploratory factor analysis using classical and Bayesian approaches were utilized to investigate and contrast nonintellective factors on learning beliefs, attitudes and practices. Under the classical approach, factors were extracted using the principal factor method, retained following Jollife's modified rule, and rotated employing Harris-Kaisser ortho-oblique rotation method, using statistical software SAS. Under the Bayesian approach, the rotated factor solution using the classical approach served as the prior factor loading matrix. The number of factors m extracted under the classical approach was also utilized as the prior information on the hyperparameter m while the hyperparameter v was obtained using $v > 2p+2$ where p is the number of variables (Rowe, 2001). The hyperparameters d_0 and q_0 were assigned empirically as $d_0 = \frac{1}{100}$ and $q_0 = \frac{1}{5}$ based on the interpretability of the generated factors. The prior population mean was obtained by computing the averages of the variables and rounding off the values to the nearest unit. Bayesian factor analysis using Gibbs and ICM algorithms was performed using Mat lab.

Results on Intellective Factors

Difference in the scores obtained between the final and diagnostic examinations was used as an indicator of the cognitive learning achieved by the student. Results showed that students under the two paradigms both had mean differences in scores that are significantly different from zero (p-values<0.0001). This implied that students gained understanding of statistical concepts in both learning paradigms. However, with allowance for error and a 95% level of confidence, the data did not provide evidence to indicate difference in the cognitive learning achieved between students taught in GE statistics under the transformative learning framework and the transmissive pedagogy (Figure 1).

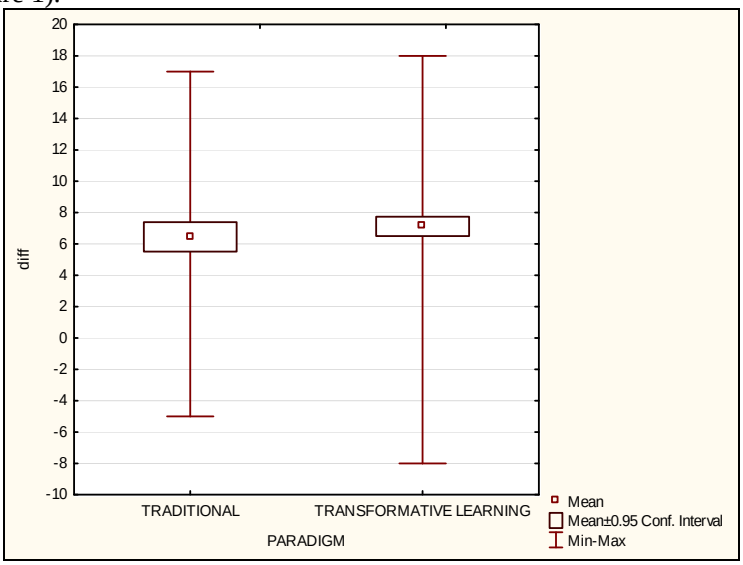

Figure 1. Cognitive learning achieved by paradigm

Results on Non-intellective Factors

Exploratory factor analysis yielded seven non-intellective factors with eigenvalues greater than 0.70. These seven latent factors accounted for 90.52% of the common variance. The overall measure of sampling adequacy is 95.61% while individual measures of sampling adequacy are at least 85% validating the use of exploratory factor analysis. Ortho-oblique rotation was employed to extract a simpler structure of the factor pattern matrix obtaining seven correlated non-intellective factors (Table 2). The questionnaire items that load highly on these 7 factors are listed in the Appendix.

In the Bayesian approach, the hyperparameters were assessed as $M = \frac{1}{100} I_8$, $Q = 0.2I_{50,}$ and $v = 103$. The prior population mean was assumed as $\mu_0 = 5e_{50}$ where e_{50} denotes a 50-dimensional unit vector. The columns of μ_0 as well as the rows of X were scaled by the variance of the columns of X for estimation and the estimated means were rescaled. Using Gibbs and ICM algorithms, seven factors were likewise generated (Table 2). Slight differences in the items found to load highly in the generated factors can be observed (Appendix).

Table 2. Seven Factors Generated using Classical and Bayesian Factor Analyses

Factor Number	Factor Name
1	Performance Assessment
2	Learning Environment
3	Teacher's Role
4	Computer-based Instruction and Web technologies
5	Learning Processes and Real-Life Applications
6	Attitude towards Learning under Transformative Learning Framework
7	Independent Learning

Furthermore, results showed significant differences between the responses of the students under the transformative learning paradigm and the transmissive pedagogy on the first five factors, namely, performance assessment, learning environment, teacher's role, computer-based instruction, and learning processes (Table 3). Students under the transformative learning framework reported higher mean scores in these 5 factors, indicating that these factors are highly perceivable and experienced in GE statistics classes under this paradigm. No significant differences were observed in the last two factors, namely, attitude towards learning and independent thinking (Table 3).

Table 3. Comparison of Mean Scores for Non-intellective Factors

Factor	Pedagogical Frameworks		p-value
	Transformation	Transmission	
1	5.34	4.65	0.0094*
2	5.23	4. 66	0.0069*
3	5.14	4.49	<0.0001*
4	5.85	3.14	<0.0001*
5	5.05	4.57	0.0478*
6	3.63	2.94	0.0950ns
7	4.62	4.49	0.4190ns

Legend: * significantly different at 5% level of significance; ns – not significantly different

CONCLUSIONS

The paradigm shift in teaching statistics from traditional transmissive pedagogy to transformative learning framework required over-all reforms which included revision of course syllabus, development of learning materials, facilitating as teacher's role, inclusion of authentic assessment, use of computer-based instruction and Web technologies, and improvement in the learning processes emphasizing real-life applications.

The appraisal study showed evidence of cognitive learning achieved by the students under both paradigms, but such learning does not significantly differ between the two paradigms. The two pedagogies significantly differ in five factors, namely, performance assessment, learning environment, teacher's role, computer-based instruction, and learning processes. Significantly higher mean scores of these factors from the students under the transformative learning paradigm indicate that innovations in GE statistics classes were implemented enthusing students towards statistical literacy.

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APPENDIX: *List of Seven Generated Factors and Questionnaire Items*

Factor 1: Performance Assessment

Classical Factor Analysis (FA)	Bayesian Factor Analysis (FA)		Item
	Gibbs	ICM	
38	38	38	The tests and assessment tools determine how much the students understood the concepts and apply them.
39	39	39	The tests and assessment tools determine the student's ability to effect improvements in his/her learning including how much his/her initial learning of the subject has changed.
40	40	40	Our teacher provided exercises, seatwork, assignments or practice sets to check students' understanding of statistical concepts or demonstration of statistical procedures.
41	41	41	Our teacher used various forms of performance assessment such as quizzes, portfolios, reflection logs, seatwork, group projects, and other scoring guides.
42	42	42	Our teacher involved students in the process of evaluating academic work, assignment or group projects.
43	43	43	The tests and grading tools in this class require one to demonstrate his/her ability to integrate statistical concepts and applications in real life situations and various areas than just simple recall from memory or lecture notes.

Factor 2: Learning Environment

Classical FA	Bayesian FA		Item
	Gibbs	ICM	
11	11	11	I was encouraged to ask questions, to experiment and to formulate my own plan of action.
12	12	12	I learned to ask questions which helped me understand the lessons.
14	14	14	The students were encouraged in this class to collaborate and support one another in group learning activities, reports, and assignments.
16	16	16	The students were free to test their own ideas and to ask questions without fear of being embarrassed or reprimanded.
17	17	17	The students were encouraged to explore their ideas and rethink/reassess their ideas in varied activities.
18	18	18	The teacher-student relationship was motivated by mutual respect for each other.
19	19	19	The classroom set-up allowed the students to be open-minded, liberal, and holistic.
	34		Our tea**c**her allowed us to work in groups to discover statistical concepts and apply statistical procedures.
36	36	36	Our teacher encouraged us to find answers and solutions through research.
	37		Our teacher is effective in teaching statistics.
44	44	44	Critical feedbacks were discreetly given in order to avoid embarrassment and unnecessary attention to the student.
45	45	45	Our teacher gave constructive feedback regarding student's individual or group/class performance.
46	46	46	Effective teaching is providing more lectures in class.
47	47	47	Our teacher explained the transformative learning paradigm at the start of the term.

Factor 3: Teacher's Role

Classical FA	Bayesian FA		Item
	Gibbs	ICM	
23	23	23	Our teacher provided varied activities and inquiry plans which helped us deepen our knowledge and understanding of statistics.
24	24	24	Our teacher guided us to learn how and where to find sources of information for concepts, questions/issues, and problems.
25	25	25	Our teacher encouraged us to share observations, reflections, and ask questions through discussions, reports, activities, and projects.
26	26	26	Our teacher discussed lessons that took into account true-to-life experiences and social realities.
27	27	27	Our teacher emphasized and summarized key points for understanding.
28	28	28	Our teacher facilitated classroom discussions by starting with our past statistical knowledge and leading us towards understanding of statistical concepts we need to learn.
29	29	29	Our teacher challenged us to uncover statistical facts and concepts in interdisciplinary contexts and build knowledge by observing, hypothesizing, experimenting, and discovering.
30	30	30	Our teacher presented tasks/problems that are analogous or applicable to the challenges faced in the real world.
31	31	31	Our teacher provided the students with activities that made us apply/manifest learning not only inside the classroom but also in everyday life.
32	32	32	When conflicting views emerged in classroom discussions, the teacher challenged the students to examine each other's perspectives and reach a common ground.
33	33	33	Our teacher encouraged us to think, solve and explain solutions to problems and not memorize formulas/procedures.
35	35	35	Our teacher provided us opportunities to reflect and revise our work.

Factor 4: Computer-based Instructions and Web Technologies

Classical FA	Bayesian FA		Item
	Gibbs	ICM	
20	20	20	This class updated us with the current trends and concepts in statistics such as the use of statistical software and talks on official statistics.
21	21	21	Various teaching and learning strategies were utilized, including the use of statistical software, to help students understand procedure and apply them in real-life problems.
22	22	22	Our teacher allowed the use of statistical software in solving statistical problems to lessen tedious computations and emphasize statistical applications.
23	23	23	Our teacher provided varied activities and inquiry plans which helped us deepen our knowledge and understanding of statistics.
34		34	Our teacher allowed us to work in groups to discover statistical concepts and apply statistical procedures.

Factor 5: Learning Processes with Emphasis on Real-Life Applications

Classical FA	Bayesian FA		Item
	Gibbs	ICM	
1	1	1	This statistics class developed critical thinking abilities by engaging the students in various discussions and problem-solving activities.
2	2	2	This class enabled me to discover key concepts in statistics through various activities, group presentations, assignments, and individual work.
3	3	3	I have learned and understood new concepts in this class since I was made to correct my past misconceptions, stereotypes and biases.
4	4	4	I learned to apply statistical concepts in real life situations in this class.
5	5	5	I learned how to apply what I know in practical terms because of the real-life applications tackled in this class.
6	6	6	Discussions in this statistics class helps in developing practical strategies to solve real-life problems.

Factor 6: Attitude towards Learning under Transformative Learning Framework

Classical FA	Bayesian FA		Item
	Gibbs	ICM	
48	48	48	The activities in this class under the transformative learning framework are interesting.
49	49	49	I prefer that this statistics course be taught under the transformative learning framework than the usual traditional approach.
50	50	50	The transformative learning framework is appropriate in teaching this basic statistics course.

Factor 7: Independent Learning

Classical FA	Bayesian FA		Item
	Gibbs	ICM	
7	7	7	I learned how to connect my new learning with my past experiences.
8	8	8	I was enthusiastic to learn new things in this class because the lessons challenged me to rethink my own ideas.
9	9	9	I learned to formulate my own plan of action in this class by looking for concepts and answers in various references/sources, and asking questions.
10	10	10	It made me reflect and be involved in the development of my own thinking.
11	11	11	This class developed my confidence since I was properly guided to perform tasks.