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Science Process Skills Development through Innovations in Science Teaching

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Abstract

This study examined the effects of combining innovative approaches in teaching general biology on the development of students' science process skills. Two intact classes of college non-science freshmen from a government-managed higher learning institution in the Philippines were compared. An instructional package based on standard tertiary level General Biology course employing multiple representations to be delivered through collaborative teaching and learning approach was designed and compared against the traditional approach to teaching. Quantitative data were obtained from the students scores in Prior Science Knowledge test and Science Process Skills rubric. Qualitative data were obtained from the analysis of students' focus group discussion. The t -test was done to determine the difference in the observed mean scores at α = 0.05 level of significance. Results showed significantly higher scores in the science process skills of students exposed to the multiple representations and collaborative learning approach. Prior science knowledge was found to have no significant correlation with science process skills. Students' science process skills were also found to differ across gender.

Keywords: Innovative science teaching, multiple representations, collaborative learning approach, traditional or expository method, science literacy, science process skills.

Introduction

Science, as an academic discipline involves learning the key concepts, as well as the processes of science. The increasing importance of science process skills in the present diverse population of students poses a serious challenge of finding ways to improve teaching as a means of elevating these educational outcomes. Recent revival of interest in developing thinking skills has encouraged added emphasis on process skills instruction[1].

To achieve these learning goals, science educators and researchers are looking for key factors, innovations and ways to improve, modify, augment or replace prevailing methods of delivering effective and meaningful learning on given sets of educational climates. At the same time, the varied needs of the present breed of students have to be met. Traditional education is failing in attaining the educational needs of the current generation of students.

Traditional or expository method has been used for many years and is still the prevalent method of teaching in most tertiary-level science classes. Researches in this area have found that this method is highly inadequate. Largely dependent on text-based, content acquisition and passive flow of fragmented concepts from the teacher to students, this method is widening the gap between valuable learning experience and the mere compliance of the academic exercise.

The use of multiple representations approach is viewed as an alternative to deal with this educational need. Multiple representations go beyond the use and communication using language, but attends to a complex repertoire of meaning making through images, sounds, prints, models, three - dimensional forms, and use of various action-based learning experiences.

Although not very new, the key importance of understanding and integrating different representational modes in learning science concepts and methods is a growing body of research. This is upon the recognition that to learn science effectively, students must understand different representations of science concepts and processes, translate them from one form to another, and coordinate their use in representing scientific knowledge. This entails understanding and relating descriptive, mathematical, experimental or kinesthetic, and analogical modes to develop knowledge of scientific concepts and processes [2].

Recent research has focused on identifying key design features of effective representations that promote successful student interpretation and learning [3,4]. Although such findings noted that multiple representations posed significant demands on both the educators and the learners, its potential value to effective meaningful learning is recognized. The governing logic of this approach is that relevant design features in representations can optimize learning styles of the students especially when complemented with teaching strategies that best suit their specific needs, like collaborative learning environments.

In higher education institutions, General Biology is a popular way for non-science majors to fulfill a general education requirement. Because it is one of the few college-level science courses required of these students, it offers rare educational opportunity to shape their science attitudes, correct misconceptions and develop skills involving the processes of science.

In the Philippines, where education remains to be the most promising agent of social transformation, the challenge to improve and upgrade the quality of education is always included among its top developmental goals[5]. Public Colleges and Universities and Private Higher Learning Institutions are however similarly granted with autonomy and academic freedom to develop their own curricula, introduce competitive instructional programs and award their own degrees[6]. Although it allows for flexibility and independence against bureaucratic interventions, it compromises the quality of learning due to the absence of rigid monitoring and feedback system. In fact, despite the trust given by the government to these institutions of higher learning, their graduates remain below par by international standards in terms of science process skills, among other learning outcomes.

Methodology

This study examined the effect of combining multiple representations approach and collaborative learning as innovations in teaching General Biology on the development of the students' science process skills. It involved a total of 115 students enrolled in a Non-Science Degree taking General Biology as a curricular requirement. Its main feature was the use of two intact classes with the assumption that they are as similar as possible to fairly compare them as experimental and control groups.

Learning Resource and Instruments: A learning package containing resources with various modes of representations was prepared. Evaluation instruments such as the Science Literacy test used to measure Prior Science Knowledge (PSK) and rubric for evaluating the students' Science Process Skills (SPS) were developed. Focus Group discussion guide was also prepared and used to draw learning insights, comments and suggestions from the students.

Intervention: The course was delivered to the experimental class following the same General Biology Syllabus as the control group. Factors that were held constant included topic sequence, duration of classes and main references. The multiple representations approach utilized the enhanced descriptive, mathematical, analogical and kinesthetic representations of biological concepts and processes. The key feature of this approach is the redundancy in the concepts and processes of representations.

Embedded in the Power point lectures were texts, pictures, illustrations and animations or simulations of biology concepts and processes. Group activities such as scientific investigation, experimental designs, puzzles and model making and case studies were included in the learning activities. Auditory enhancement was accomplished by the use of speakers for computer simulations and animations.

Analysis: For statistical comparison of scores, independent and paired samples *t*-test were done at $\alpha = .05$ confidence level. A *p-value* of < 0.05 was considered as the criteria of significance. The qualitative data obtained from the focus group discussion were organized into themes and analyzed for trends in frequency and percentage of similar and related ideas.

Results and Discussion

Pre-Intervention: Prior to the implementation of the multiple representations collaborative learning approach to the experimental group, Students in both groups completed the Prior Science Knowledge test to evaluate prior learning. The results of pre-intervention tests are shown in Tables 1.

Table 1
Independent samples *t* - test of Prior Science Knowledge (PSK) mean scores

Variables	Obs	Mean	StdDev
Control	61	16.84	3.35
Experimental	55	16.69	3.31
Diff		0.301	
t= 0.240 df = 115 p = 0.811 H_o: control = experimental Decision: Since p-value=0.811(significant) is greater than α=0.05, H_o is accepted.			

As shown in Table 1, the mean score in the PSK of the control group is 16.84 while the mean score of the students from the experimental group is 16.69. Aimed at measuring the students' prior knowledge in science, these results show that the students in both groups have low prior science knowledge, which may indicate poor understanding of the nature of science and the science inquiry process. This result satisfies the homogeneity requirement between the two groups prior to the implementation of the research intervention.

Science Process Skills: The cumulative score for Science Process Skills is 20 obtained from two individual and 2 collaborative activities. The mean score of both groups of students is summarized in table-2. For the students in the control group, the mean score is 12.52, which is 62.60% of the perfect score of 20 points. It is evaluated as a fair display of basic and integrated science process skills. For the experimental group, the mean score is 15.20, which is 76% of the perfect score and is 18% higher than that of the control group.

The independent samples *t*-test for the two means showed that there is a statistically significant difference between the two groups ($p< 0.05$). The differing impact of the traditional and multiple representations collaborative learning approaches on students' Science Process Skills can be attributed to the difference in their priority or focus. Development of skills in the processes of science is not among the priority of the traditional science class. The teaching of these skills through the traditional lecture mode is faced with problems such as time constraint. Likewise, the limited opportunity for students to participate in inquiry and hands-on activities may not serve the students' need for more enhanced psychomotor development.

Table 2
Independent Samples *t*-test of the mean score in the Science Process Skills

Variables	Obs	Mean	Std Dev
Control	61	12.52	2.05
Experimental	55	15.20	2.94
Diff		-3.61	
t=-4.330 df = 115 p = 0.0001 H_o: control = experimental Decision: Since p-value =0.0001(insignificant) is less than **α**=0.05, H_o is rejected.			

On the other hand, the multiple representations collaborative learning approach focused on improving the students' conceptual understanding[7], the development of higher order learning skills[8] and in the students' general development of science literacy[9]. These were achieved when students were provided with opportunities for interaction and collaborative participation in science inquiry activities. Evidently, the students in the experimental group have outperformed the control group.

Factors that Influence the Efficacy of Multiple Representations Collaborative Learning Approach: Prior Science Knowledge: One of the theoretical bases on which this study was conceived lies on the importance of prior science knowledge (PSK) in knowledge construction and attainment of more meaningful learning from academic instructions. This result however revealed no statistically significant correlations between the two scores at $p< 0.05$. In a related study exploring the relationship between grades and student attitude toward the subject matter and teacher, a low correlation coefficient was also obtained implying that attitude toward the subject and teacher had no significant bearing on learning outcomes [10].

And while literature strongly supports the importance of prior knowledge in future learning, this trend was not observed in science process skills. This is however viewed as a promising observation because it indicated a possible remedy for past learning deficiencies. If effective learning would greatly depend on a good prior knowledge base, then the poorly educated students would be permanently disadvantaged over those with better past learning opportunities. This is a logical assumption considering the high dropout rate in the study site of this research, where students stop by the time they reached the second year in college. Here, the multiple representations collaborative approach could serve as a remedy to correct past misconceptions and augment poor prior academic background.

A good prior knowledge is known to optimize learning, the absence of which can be remedied through innovations in science teaching. This study provides evidence that collaborative work, kinesthetic activities, and analogical learning experiences can augment past learning deficiencies, as shown in the science process skills of students that received instruction in multiple representations collaborative learning approach.

Other Demographic Factors: This study intended to explore other demographic factors that may have contributory effects to science learning and science process skills development. But since the respondents were of narrow age range belonging to middle and lower middle socio-economic classes, and residing in rural communities, only the gender factor was considered.

Results of independent samples *t*- test (Table 3) show that mean scores in SPS of male and female students are significantly different (p<0.05).

Table 3
Independent samples *t*- test of the mean Science Process Skills across gender

Variables	Obs	Mean	Std Dev
Male	30	17.35	2.232
Female	25	13.83	2.455
Diff		3.592	
t= 5.215 df = 53 p = 0.000 H_o: male = female Decision: Since p-value =0.0001(insignificant) is less than **α**=0.05, H_o is rejected.			

This result shows that male and female demonstrated difference in the science process skills when exposed to innovative teaching approaches in favor of male students. That this group performs better in science achievement was a common finding in many educational researches. In a comprehensive review of studies about correlations among ability, achievement, and gender, it was reported that male students had slightly better cognitive ability than females, and that the observed relationship was strongest in biology and physics[11].

Gender differences in science, in favor of the males, have been attributed by many researchers to factors such as female students' lack of exposure to science-related activities outside the classroom, gender biases of teachers with respect to strategies for asking questions and delivering answers, cultural influences from society and school, differences in spatial abilities, cognitive abilities, and mathematics background[12,13]. This result is consistent with the findings of the study conducted by Wehrwein among undergraduate psychology students where the majority of male students preferred various modes of instructions while the majority of females preferred single mode of instruction with preference toward visual learning[14]. There are also gender differences in learning styles specific to science, math, engineering and technology among students that must be considered in the classroom. First, in general, females have less experience in the hands-on application of learning principles in laboratory settings than males. Laboratory works require problem-solving schemes, accompanied by use and manipulation of tools and equipment, and spatial relation skills that few female students possess.

Another possible difference in the skill development of males and females is their differential perception of group dynamics. Research studies by American Association of University Women and Children have found that most females prefer non-competition activities in the classroom. Conversely, most males greatly enjoy competition as a method of learning and play.

Students' Learning Insights: Figure 1 summarizes the students' responses to the guide questions in the focus group discussion. The most preferred activities of the students for the collaborative learning were data gathering (88%), designing experiments (82%), experimentation (80%), problem -solving (79%), model making(76%) and drawing conclusions (58%). Of these, male students preferred problem solving and designing experiments best while female students preferred data gathering activities. Research findings such as these, together with the observations of teachers and parents from the Office of Special Education Program work groups and others organized by the National Science Foundation in conjunction with the American Academy for the Advancement of Science, highlight the need for classroom strategies that will improve the ability of students to apply knowledge and skills to real world situations[15]. The students also appreciated the opportunity to work in small groups performing activities and discussing the lessons.

This was something rarely done in their other courses, according to them. It was also mentioned that students developed greater appreciation of the role of classroom learning in social interactions.

Of the various representations used in the experimental group, experimentation in small groups is one form that is known to enhance process skills among students and the use of enhanced multimedia learning resources.

The literature also implied that computer simulations are good supplementary tools for classroom multimedia supported, highly interactive, collaborative computer simulations are appealing because of their potentials to supplement constructivist learning. They are also useful tools for improving students' hypothesis construction, graphic interpretation, and prediction skills. In the study of Kennepohl where the benefits of computer simulations in a first-year general chemistry course was examined, he found that the combination of simulations and laboratory exercises resulted in better knowledge on the practical aspects of laboratory related activities[16].

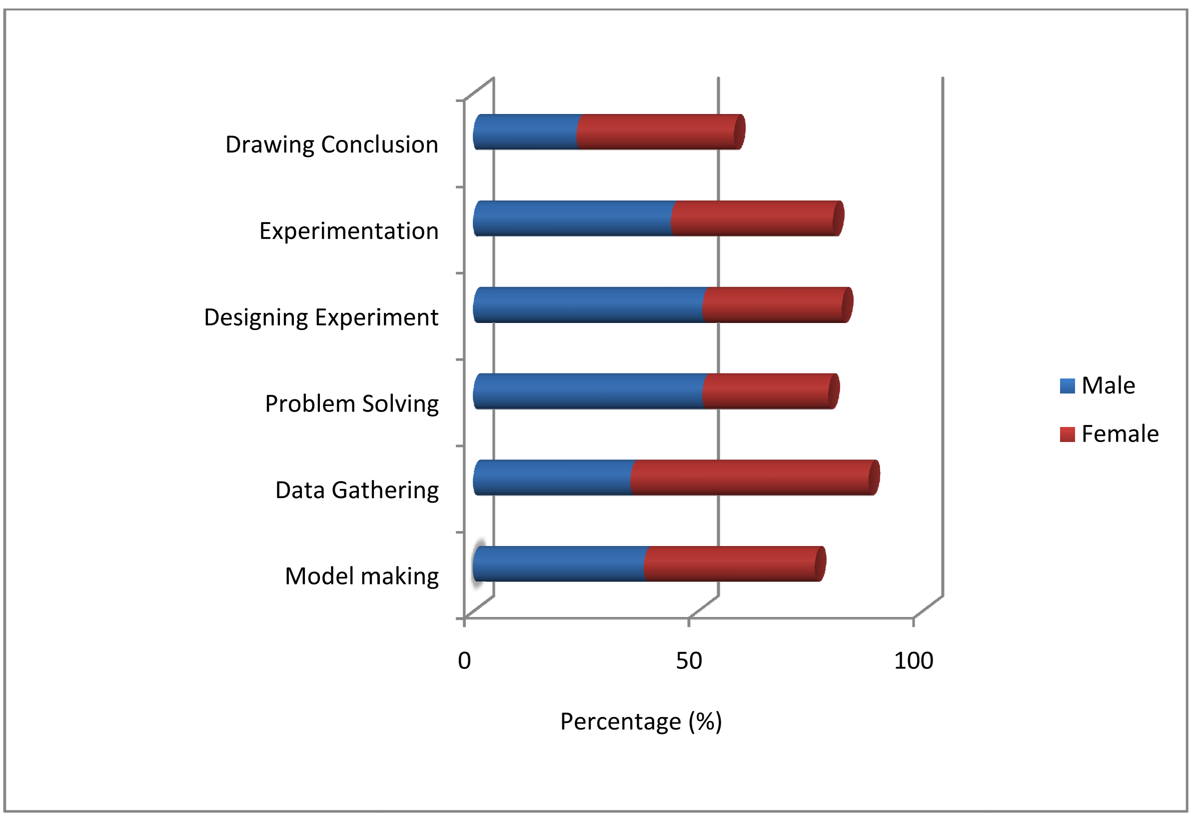

Figure-1
Processes of Science the students preferred for collaborative learning

Varying the conditions under which learning take place makes teaching more difficult, but produces better outcomes. In this study, varying conditions by incorporating multiple modes of representations appeared to pay high dividends for the effort exerted, at least within the bounds of the educational context of this study. In the language of cognitive psychology, when learning occurs under varied conditions, key ideas have "multiple retrieval cues" and are thus more "available" in memory. When learning becomes integral part of the long- term memory, the learning experience becomes more meaningful and valuable.

In view of globalization, the aim of education is to help bridge the gap between those who globalize and those who are globalized in the local, national, regional and International levels. Teaching to live together is synonymous with developing an understanding and appreciation of interdependence in sprit of respect for the value of pluralism, mutual understanding and peace[17]. In sciences teaching, conceptual learning and science process skills enhancement of students are ways by which science education can provide solid contribution to global progress.

Conclusion

Within the framework of this study and the context of the study site of this research, the following conclusions are drawn: i. The college freshmen students demonstrated statistically significant gain in Science Process Skills when exposed to innovative teaching approach compared to those exposed to traditional or expository teaching approach. ii. For students exposed to innovative teaching approach, science process skills cannot be correlated with their prior science knowledge. iii. Male students have better science process skills when exposed to innovative teaching approach.

Acquisition of science process skills can have a profound impact on student success in college science classes. In this study, the use of multiple representations collaborative approach showed significant improvement in the students' science process skills, the strength of the effect has no significant bearing on prior knowledge but is enhanced among male students.

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