2. Methodology

2.1 Materials

Lessons: Three lessons of fifty minutes duration each on sexual reproduction in flowering plants were prepared according to Klopfer's taxonomy of learning objectives and taught. Each lesson contained three parts, namely:

- the operational teaching and learning objectives defined according to the categories and subcategories of Klopfer's taxonomy. These were carefully selected to integrate the acquisition of knowledge and comprehension, observation and measurement, perception of a solution and deciphering the problem underlying it [7, 3] and the application of the knowledge learned in new contexts in problem solving;
- pedagogic activities including the inductive and deductive approaches to thinking as mechanisms for creating, elaborating and appropriating new knowledge for problem-solving; and
- the consolidation of the key competencies developed.

2.2 Researcher-made achievement test [8]

Twenty multiple choice test items, each with four alternative answers of which only one was the most correct were used to test the operational learning objectives in the three lessons. The test items were arranged in the pre-test according to Klopfer's[9] taxonomy of learning objectives as follows:

- seven questions on "knowledge and comprehension", four of which were based on "knowledge of facts" (subcategory A1) – Q1, Q3 and Q9; one on "knowledge of scientific terminology" (subcategory A2) – Q2; two on "knowledge of classifications, categories and criteria" (subcategory A6) – Q7 and Q12; and one on "comprehension" (subcategory A10) – Q8;
- three questions on "process of scientific inquiry I – observing and measuring", all testing skills in "observation of objects and phenomena" (subcategory B1) and "description of observations using appropriate language" (subcategory B2) – Q4, Q5 and Q6;
- four questions on "process of scientific inquiry II – seeing a solution and deciphering the problem behind it all testing the "recognition of a solution" and "formulation of a working hypothesis" (subcategories C1 and C2) – Q10, Q11, Q17 and Q18; and
- finally, six questions on "application of scientific knowledge and methods", with one question testing the "application of scientific knowledge and methods to new problems in both the same field and different fields of science" (subcategories F1 and 2) – Q13; and five others testing the "application of scientific knowledge and methods to problems in new contexts" (subcategory F3) – Q14, Q15, Q16, Q19 and Q20.

The roots and position of the distracters were altered and the question numbers shuffled to minimise familiarity effect due to pre-exposure in the post- and confirmatory post-tests. The validity and reliability of test items were assured by regional pedagogic inspectors of science education in the Ministry of secondary education.

a) **Questionnaire:** A questionnaire of seven questions was designed to collect categorical data on confounding variables: sex of respondents; age (≤13, 13 – 14, and >14) and socio-economic backgrounds.

b) **Sampling:** A sample of 245 second year students of general secondary education drawn from two public and two lay private schools in Yaoundé was used. Sampling was by a combination of cluster and simple random lottery methods, [10, 11].

c) **Data collection:** Data were collected between September and the second week of December, 2013. In each class the questionnaire on the confounding variables was first administered, followed by the pre-test, and then teaching. Immediately after this the post-test was administered with the confirmatory post-test coming six weeks after.

d) **Data treatment and analyses:** Descriptive and analytical data were generated by SPSS v.20.0. Categorical data on confounding variables were sorted, coded and keyed into the SPSS variable view spreadsheet. Codes on respondent performances were also defined on the SPSS variable view spreadsheet followed by keying-in of the marks against the corresponding codes. Both data were verified for errors and corrected accordingly. Statistical analysis was by use of a within-subjects paired-sample t-test. The mean performances between treatments (pre-test, post-test and confirmatory post-test) were correlated and compared for levels of significance within the lower and upper bound limits of the confidence interval of 95%. A one-way Analysis of Variance followed by a *Post Hoc Least Significant Difference* multiple comparisons were used to confirm or refute the changes observed between the mean pre- and post-test performances [12].

3. Results and Discussions

From Table 1, mean performances significantly increased from the pre- to the post-test in the different categories of Klopfer's taxonomy. A similar change was observed when all the categories were taken together. Conversely, the standard errors of the mean and standard deviations all show slight decreases between the pre- and post-test performances in the different categories. An interesting result is the occurrence of a moderate significantly positive correlation between mean pre- and post-test performances in all the categories except in that of seeing a solution and identifying the problem underlying it which shows no significant correlation; $r = .12$; $\rho = .06$.

Table 1: Descriptive data, t-critical values and levels of significance for correlated means between pre- and post-test performances grouped by Klopfer's taxonomic categories

Category	Mean Score Pre-Test	Mean Score Post-Test	Std Error of Mean Pre-Test	Std Error of Mean Post-Test	Std Dev Pre-Test	Std Dev Post-Test	Var Pre-Test	Var Post-Test	R and P-Values	T-Critical and P-Values
Knowledge & Comprehension	3.67	4.78	.084	.079	1.31	1.21	1.72	1.46	r = .20; ρ = .002*	t(235) = -10.68; ρ = .000*
Observing/ Measuring	1.33	2.08	.055	.052	.87	.81	.75	.65	r = .30; ρ = .000*	t(235) = -11.85; ρ = .000*
Seeing a solution & identifying the corresponding problem	1.32	2.53	.065	.064	1.02	.98	1.03	.96	**r = .12; ρ = .06**	t(235) = -14.00; ρ = .000*
Application of scientific knowledge/methods	1.31	3.89	.071	.075	1.11	1.15	1.22	1.33	r = .20; ρ = .002*	t(235) = -27.84; ρ = .000*
Overall performance	7.60	13.29	.151	.159	2.38	2.44	5.66	5.93	r = .32; ρ = .000*	t(235) = -30.82; ρ = .000*

**Statistically significant, ρ < .05*

Comparisons between paired performances in the oval tests, namely: pair 1 –overall post- and overall confirmatory post-tests; and pair 2 –overall pre- and overall confirmatory post-tests revealed a slight drop in performance between overall post- and confirmatory post-tests. Despite the slight drop there is no significant difference between the two, t(235) = 1.69; ρ = .09. This goes along with a very strong positively significant correlation of r = .55; ρ = .000. However, when mean overall pre- and confirmatory post-test performances were compared there was a very significant improvement in performance between the pair representing t(235) = - 31.59; ρ = .000. This goes along with a moderately positive and significant correlation. These results are represented in Table 2.

Table 2: t-critical values and levels of significance for correlated means between overall pre-, post-and confirmatory post-test performances taken together

Pairs	Category Compared	Mean Performance	Std Error Mean	Std Dev	Var	R And P-Value	T-Critical And P-Value
1	Overall post-test &	13.29	.159	2.44	5.93	r = .55; ρ = .000*	**t(235) = 1.69; ρ = .09**
	Overall confirmatory post-test	13.05	.135	2.08	4.31		
2	Overall pre-test &	7.60	.152	2.38	5.66	r = .30; ρ = .000*	t(235) = -31.59; ρ = .000*
	Overall confirmatory post-test	13.05	.135	2.08	4.31		

**Statistically significant, ρ< .05*

Table 3 reveals that analysis of variance on the possible effect of confounders on the post-test performances of respondents showed no significant difference, ρ>.05. A *post-hoc* multiple comparison further confirms this finding at all the levels of the confounders. These results confirm that the changes observed in the post-test performances of respondents were due to the use of Klopfer's taxonomy in guiding teaching and not to the confounder.

Table 3: ANOVA statistic and post-hoc multiple comparison of the possible effect of confounders with mean overall post-test performances

Confounder	*Anova Statistic and Level of Significance*	*Post-Hoc Multiple Comparison Level of Significance*
Age	F(2, 233) = 0.520; ρ = .60	ρ > .05
Sex	F(1, 234) = 3.960; ρ = .05	
Sponsor	F(4, 231) = 1.003, ρ = .41	
Profession of sponsor	F(4, 231) = 0.643; ρ = .63	
Educational level of sponsor	F(4, 231) = 0.844; ρ = .50	
Marital status of sponsor	F(2, 233) = 0.362; ρ = 70	

Results in the knowledge and comprehension category demonstrate that acquired knowledge makes more sense and can be better conserved if understood. For example, most young people in Cameroon today can reproduce verbatim the wordings of several songs in Lingala by Congolese musicians. This is an indication of knowing, but when asked to explain the meaning of the song, they confess not knowing what it means. In Klopfer's taxonomy, the identification of a fact, concept, procedure or theory in a different context as well as its translation from one symbolic form to another constitutes understanding. During the experiment, we combined the acquisition of specific, clear and precise knowledge with their identification in different contexts. For example, "*The most important difference between a simple and a compound flower is…*" This question is based on Klopfer's subcategory A10, which is *Identification of a fact, term, concept, trend, principle or theory in a new context.* Learning about the characteristics of different types of flowers in subcategory A.06 and extending the knowledge to identify the most important difference between different categories of flowers is evidence of understanding. Hence, knowing without understanding does not make sense and understanding favours greater conservation of knowledge. This justifies the bivalent nature of Klopfer's taxonomy.

The observing and measuring category has important significance as biology is essentially an observational science. Effective observation and measurement makes learning more meaningful as the learner explores what is real and concrete before moving onto the abstract which can only be perceived by logical and rational reasoning. The learner must be helped to make effective use of the five senses. Bachelard [13] holds that a child from its first contact with life finds itself confronted by a world that poses a lot of questions and proceeds to find answers to these questions either individually or through interaction with his entourage. Due to the lack of scientific orientation in the learner's initial observations, Bachelard refers to knowledge acquired this way as *"common knowledge"*. Effective interaction with the surrounding requires effective observation and measurement which promotes the development of thinking. Such is the scenario demonstrated by the respondents' performances in the post-test. This implies that Klopfer's taxonomy can help learners to restructure their observations and therefore learn in a scientific.

In perceiving a solution and identifying the problem behind it, the post- and confirmatory post-test results consolidate the fact that Klopfer's taxonomy contributes to the acquisition of problem identification and solution skills. During the experiment, questions like: *Some small and dull coloured flowers produce many light pollen grains. Producing many light pollen grains is know-how to solve a problem. Identify the problem...* Answering this question requires skills in linking observations of events and phenomena to their possible causes or contributing factors. After the introduction of Klopfer's taxonomy, learners acquired skills that enabled them to start linking solutions observed in nature to the possible problems behind such solutions. This was possible because we combined the introduction of Klopfer's taxonomy with the deductive way of thinking which enabled respondents to associate solutions to problems and vice versa. Problem identification through association with their solutions contributes to the development of the learner's critical thinking skills, [7]. The absence of a significant correlation between the mean performances before and after experimentation ($r = .12$, $\rho > .05$) in this category further confirms this. The foundational basis of this approach is that if learners can identify solutions in nature and build on such solutions to decipher the problems underlying them, then they can equally reinvest such knowledge to identify problems in the human society and apply similar procedures to think out possible solutions to them. Benyus[14] describes this type of thinking as bio-inspiration – learning inspired by nature's know-how.

In the application of scientific knowledge and methods category, we associated a rubric that emphasised the reinvestment of the knowledge acquired to other areas in order to establish the linkages between them. Identifying problems in nature and the way nature sets about solving them can also be reinvested to seek explanations to similar problems in different areas including the human society. With the use of Klopfer's taxonomy to guide lesson preparation and teaching, the learner is systematically helped to establish links in his knowledge with other fields and the society. This constitutes the associative basis of learning as posited by Pavlov and Skinner [15, 16] in their behavioural theories of learning. Such skills and competencies enable learners to handle abstractions and logical operations as a result of interaction with their physical and the socio-cultural environments, [17, 18].

4.Conclusion

The results of this study led to the following key inferences:

Firstly, Klopfer's taxonomy can facilitate the construction and elaboration of new knowledge. For example, in flowering plants, reptiles, birds and mammals, the male and female reproductive cells are very wide apart and this imposes the necessity to bring them close enough to one another for copulation to occur. In insect and bird pollinated flowers, bringing reproductive cells together for copulation involves attraction and baiting. The plant develops large brightly coloured petals and sweet scented nectar. The bright colours of the petals and the sweet scent of the nectar play the role of bait, attracting pollinators to the flower. In the process pollen grains are transferred between anthers and the stigma. This phenomenon of attraction by bright colours finds its counterpart in animals such as the bright colours of male *Agama* lizards, and peacocks that attract their female counterparts for copulation. The sweet scented nectar in flowering plants also finds parallels in male dogs, goats and sheep that produce strongly scented pheromones to attract females for copulation. Secondly, constructed and elaborated knowledge can be appropriated to seek solutions to problems in new contexts. Striking similitude exist between baiting in flowering plants and the baiting of hooks with earthworms to catch fish as well as baiting hunting traps to catch game. Rat and mice poisons are prepared by baiting poisonous substances with crayfish or fish to attract them. By reinvesting knowledge learned in one context to other contexts, it is possible to appropriate such knowledge to innovate and seek solutions to problems in new contexts. In technology, mankind has shown evidence of copying the flowering plant's know-how to solve human health problems such as using drip sets to introduce drugs directly into the bloodstream; and intubation syringes and needles for introducing chemical substances directly into the stomach of laboratory animals all of which mimic the structure and function of the pollen tube and the male copulating organ in mammals. Establishing linkages and associating knowledge and methods in this way facilitates the construction and elaboration of new knowledge as well as the acquisition of problem-solving skills. This should lead to the development of self-efficacy which according to Bandura [19] is the belief in ones capabilities to organise and execute the sources of action required to manage prospective problems.

Study in progress aims to find out the effect that using Klopfer's taxonomy to guide lesson preparation can have on promoting the development of inferential thinking skills, the acquisition of action competence and therefore autonomy of decision and action and consequently self-reliance by learners.

References

[1] U. Zoller, The Isreali environmental education project: A new model of interdisciplinary student-oriented curriculum. *Journal of Environmental Education.* 18(2), 25-31, 1987.

[2] E. Noumi, *Didactique des sciences de la vie et de la terre (SVT) illustrée par des exemples et docimologie :*

Manuel des professeurs des lycées et collèges. Yaounde: Edition GIC ICSSC. (reprographied), 2008.

[3] G. N. Nditafon, Using Klopfer's taxonomy to implement the effective teaching of biology and environmental education – a Masters II thesis submitted to the UNESCO Chair of the University of Marien Ngouabi – Congo Brazzaville, for science of education and evaluation in the Central African Sub-region, 2012.

[4] A. Hofstein, and R. Yager, Social issues as organizers in sciences education in the 80s. *School science and mathematics.* 82(3), 539 – 547, 1982.

[5] R. Miller, Science teaching for the citizen of the future. Science education, 68(4), 1984.

[6] P. Hurd, Scientific literacy: New minds for a changing world. *Science education.* 82(3),407 – 416, 1998.

[7] E. Noumi, Novel Approach to Promote Logical Thinking among Higher Education Students: a Lesson plan on the coconut fruit in second year of the Higher Teachers' Training College of the University of Yaoundé I, 2014.

[8] N.J. Salkind, Exploring research. Prentice Hall, New Jersey, 2000.

[9] L. E. Klopfer, *Student behaviour and science content categories and subcategories for a science program.* Pittsburg: Pittsburg University Press, 1970.

[10] G. De Landsheere, *Dictionnaire de l'évaluation et de la recherche en éducation.* Paris: PUF, 1979.

[11] M. E. Amin, *Social science research: Conception, methodology and analysis.* Uganda: Makerere University Printery, 2005.

[12] S. Landau, B.S. Everitt, Statistical analysis using SPSS, Chapman & Hall/CRC Press, London, 2004.

[13] G. Bachelard, *La formation de l'esprit scientifique: Contribution a une psychanalyse de la connaissance objective.* Paris : ed. J. Vrin, 1938.

[14] J. M. Benyus, *Innovations inspired by nature.* New York: William Morrow & Company, 1997

[15] I. P. Pavlov, *Conditioned Reflexes: An Investigation of the Physiological Activity of the Cerebral Cortex.* Translated and Edited by G. V. Anrep. London: Oxford University Press. Available online, 1927.

[16] B. F. Skinner, *Contingencies of reinforcement: a theoretical analysis.* New York: Appleton-Century Croft, 1969.

[17] J. Piaget, *Psychologie et pédagogie.* Paris: Denoël, 1969.

[18] L.S. Vygotsky, *Thoughts and language.* Cambridge: Massachusetts, MIT Press, 1962.

[19] A. Bandura, The role of imitation in personality development. *Journal of Nursery Education.* 18(3), 207-215, (1963)