Study on the Effectiveness of Hypothesis-Experiment Class (HEC) Approach for Interest and Performance in Natural Science - High schools in Analamanga Region in Madagascar -

Sarah Amour RAVELOSON, Hiroaki OZAWA, Rina FUKUCHI

Global Education course, Naruto University of Education

Abstract

Previous research shows that dealing with social-scientific issues allow students to connect their learning with their study to develop positive skills and attitudes. To this end, the Japanese problem-solving approach called the HEC class is used during experimental research. This paper focuses primarily on the extent to which performance and attitude in natural science subjects may be related to student engagement in Scientific subjects. Our second objective was to evaluate the effectiveness of the Japanese problem-solving approach, known as the Hypothesis, Experiments, Class (HEC). In general, the average scores of the students who chose to study science were higher than those of the non-scientific groups especially on situational interest and self-efficacy. The results also suggest that the main variable that influenced the study and career commitment related to natural science was students' self-efficacy, with a regression coefficient of 0.63. After that, the intervention of HEC increase their situational interest, where the interest in new activity and less complication have improved the most. In terms of performance, not only the total score greatly improves from 30.76% to 42.58% of the average but there was also an improvement found in both the lower- and higher-level cognitive skills.

Keywords: Natural Science, Self-efficacy, Hypothesis-Experiment Class, Interest, Performance

1. Introduction:

A) Background

Education has emerged as a powerful means to improve human skills and knowledge. Nowadays, scientific subjects are better known as Science, Technology, Mathematics, and Engineering (STEM). This educational initiative was intended to equip all students with critical thinking skills that would enable them to solve problems creatively and, ultimately, be more competitive in the workforce (White, 2014).

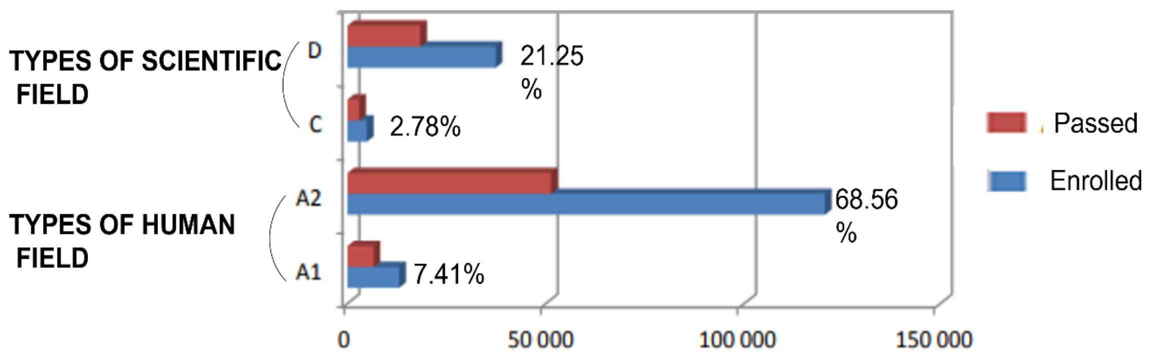
The purpose of increasing participation and performance in STEM should not be seen as contradictory to other educational goals such as improving reading, literacy, language acquisition, and historical, social, and cultural knowledge. STEM learning and non-STEM learning are interrelated (Marginson et al., 2013).

Despite the tremendous natural resources of Madagascar, the country is a developing country with a low economy. An education system that enhances interest in science education would promote this field, increase the number of scientists continuing their efforts, and bring renovations to ensure the management of natural resources.

Some reforms have already enhanced the high school curriculum as part of the implementation of the Education Sector Plan 2018-2022. It was aimed to improve the quality and efficiency of education to meet new approaches adopted in higher education and work demands (Ministère de l'Education Nationale [MEN] et al., 2017).

In upper secondary schools, the separation of fields of study occurs from the second year of high school (MEN et al., 2017).

Regarding General Education all over Madagascar, low enrollment in scientific fields was perceived at the National Baccalaureate examination of 2018. In Figure 1, we can see that options D and C, which are types of scientific fields, are about 24 % of the total enrolled in (Ministère de l'Enseignement SUPérieur et de la REcherche Scientifique [MESUPRES], 2020).



D: majoring in Natural Science, Physics, Chemistry, Mathematics
C: majoring in Physics, Chemistry, Mathematics
A2: majoring in Literary subjects in general
A1: majoring in Language subjects

Figure 1. Student enrollment and admission in baccalaureate examination of general education candidates (N=175,623) based on (MESUPRES, 2020)

Regarding enrollment per school, the proportion of students enrolled in scientific options per school in the Analamanga Region which is a region central in Madagascar and contains the capital Antananarivo is described as follows. After calculating the average of the raw data provided by the Ministry (Service des Statistiques et de la gouvernance des Systèmes, 2020), it was found a rate less than 25% of students enrolled in science studies in 16 to 24 schools during the past three years and about four to seven schools have 0 % of students enrolled in science studies (Raveloson, 2021).

There could be numerous reasons for this lack of participation in science majors. The survey results conducted in 2021 show that approximately 40% for both female and male students during the survey reported their low performance in science subjects as the reason for nonparticipation in the science field. After that, almost 20% of female students cited the significance of career planning, while roughly 20% of male students cited an interest in literary (Raveloson, 2021).

B) Literature review

Numerous studies have been conducted related to the effectiveness of studying science by addressing problems from real life; this allows students to connect what they are learning in class to their everyday lives. This approach guides students down a scientific career path (Holbrook & Rannukmae, 2007). It was found also that interest could be promoted even among slow learners. A classroom activity that shows a connection of course materials with students' lives will empower students' motivation and learning (Hulleman & Harackiewicz, 2009).

Hasni and Potvin (2015) found that, in addition to family and self-efficacy, the teaching method provided by the school was largely involved in promoting the development of student's interest in science and technology. They mentioned the importance of teaching methods that allow students to make connections between what they learn in school and their lives.

Connecting the course and daily life contributes to a more engaged and motivating learning experience for students; one of the problem-solving approaches is detailed below.

Dr. Kiyonobu Itakura developed the Japanese technique for problem-solving known as Hypothesis-Experiment Class (HEC; Kasetsu Jikken Jugyou; 仮説実験授業). The central concept of the HEC is research-based. It is about explaining fundamental rules and principles, allowing the learner to make predictions about new events, and recognizing laws that can only be solved through experimental trials to validate a hypothesis (Itakura & Funahashi, 2019).

To validate a hypothesis, this method requires students to formulate predictions and recognize laws. This teaching strategy could increase students' interest in and performance in science by allowing them to broaden their understanding through the works of a wonderfully creative mind (Itakura & Funahashi, 2019).

The Figure 2 shows the different steps of the HEC class, which are composed of the problem, expectations, discussion, and experiment.

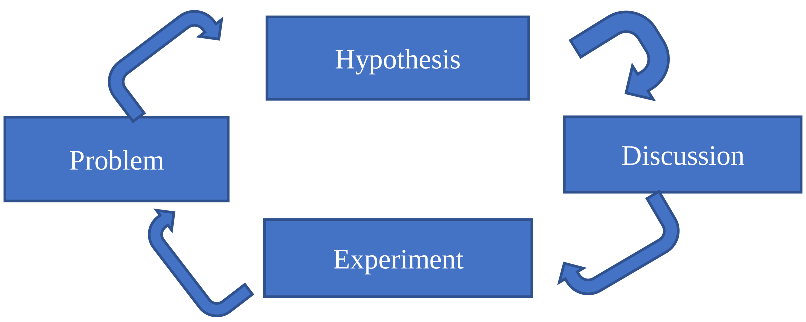


Figure 2. Main structure of HEC method

C) Objectives of the study

Poor performance in scientific subjects was found to be the main reason for low participation in the scientific field following the study cited above. In other words, poor performance causes students to not choose a scientific option. Additionally, it was discovered that interest has been reported a reason also for their choice. Indeed, interest is a further consideration when selecting a course of study and career route (Harackiewicz, 2016).

This study aims to determine the following:

• The factors that have the most influence on students' field decision

To achieve the objective, we examine the characteristics of students who have chosen to be in the scientific field by observing criteria such as gender, interest in science, performance in science, self-efficacy, and decision-making. Then, the existing relationships between factors, such as decisions and the others stated above is analyzed.

• The effect of the teaching method focusing on the problem-solving approach called Hypothesis-Experiment Class or HEC on the promotion of interest and performance of students in natural sciences (Life Science and Earth Science) during our intervention.

Hence, we check the improvement of students' interest and performance in natural science to conclude the effect of our intervention on their decision to choose the science field.

2. Methodology:

A) Sample

Regarding the sampling, random selections were taken in order to compile a representative sample from two high schools. As a result, four classes of first-year student were chosen. A total of 217 students from two schools, School A and School B, were registered in our pre-survey. However, 204 students took the test during the post-test. We only kept those who were present for every lesson as a result of the high rate of students' absence. The survey was conducted in May and June 2022, towards the end of academic school year. In general, School A located in suburban area is more advantageous in terms of infrastructure and support compared to school B which is located in rural area. However, in terms of performance, the averages of the examination score on natural science (life and earth sciences) are not so distinct with 10.86 and 9.79 out of 20 for the two classes in school A and 9. 48 and 9.95 out of 20 for the two classes in school B.

B) Research instruments

The questionnaires during the investigation included open-ended questions to obtain their direct opinion. Also, we had Likert scale questions with 4 levels of agreement with a variety of indicators as follows:

- Indicators of situational interest related to natural science (life and earth sciences) as this type of interest is externally induced; questions were structured to reach certain dimensional sources of interest: novelty, challenge, demand for attention, intention to explore, immediate enjoyment (Chen, et al. 2001).
- Indicators of individual interest related to natural science (life and earth sciences), in contrast to the previous one, highlights the stable preferences of individuals for specific content (Harackiewicz, 2016). Some questions from the TIMMS 2019 questionnaire (International Association for the Evaluation of Educational Achievement [IEA], 2018) focusing on the utility and v
- alues of science in personal life, social life, and the development of the country for students were used in this work.
- Self-efficacy indicators related to natural science (life and earth sciences). The belief that people have in their abilities, and their performance, is one of the key determinants of engagement (Maddux, 2022). The questions were built to examined the student's belief in relation to obstacles, challenges, abilities in comparison to classmates, and personal viewpoint. For that, some questions from Hasni and Potvin (2015) work were used.
- Indicators of the decision to pursue study and career related to natural science. This section measures students' planning and commitment to natural science (life and earth sciences). It investigates students' decisions about their availability, personal plans, high school studies, college studies, and career plans. To do this, some questions were taken from Hasni and Potvin (2015).

In order to evaluate student’s performance before and after our intervention, pre-test and post-test questions were elaborated.

The questions were designed to have a different level of difficulty following Bloom’s taxonomy.

Bloom's taxonomy is a series of cognitive skills and learning objectives arranged in a hierarchical model. The different levels of Bloom's taxonomy are remembering, understanding, applying, analyzing, evaluating, and creating (Cummins, 2019).

Additionally, concerning the lesson topics, three topics in natural science lessons were selected by adopting the Malagasy curriculum in first year of high school (MEN, 2019). The osmosis subject and the distillation topics—simple distillation and steam distillation—were developed during the intervention and these topics were the content asked in the performance test. At the time we came to visit our sample classrooms, they had completed the three lesson topics with their teacher some months ago, then we were able to ask them questions about those topics in pre-test.

Finally, for the analysis of the statistical data, we used the software Microsoft Excel and R during processing to highlight the distribution of the data graphically, F-test, t-test, and multiple regression analysis.

3. Results and discussions

A) Relationships between students' choices and other factors

Attitudes

Several questions were created to get information about students' academic direction choices. The first question concerns the student's choice of field for the following year. We have three options such as L: Literary Study, S: Scientific Study, OSE: Organization, Social, and Economics, the latter of which was recently incorporated into high schools. For the purpose of simplification, we will make reference to the students who chose to be in Literary study as L students, the students who choose to be in Scientific Study as S students, and the students who choose to be in Organization, Social, and Economics as OSE students from this point forward. About 123 students, or 57% of the total students, chose scientific studies, compared to 31% in the literary field and 25% in the OSE field. From this we can infer that more than half of the students are willing to pursue the scientific field. Our survey reveals that the majority of the students who participated in this study are interested in scientific field as early as their first year of high school.

To get an overview of the characteristics of students who have already thought about going into scientific studies, the summary of the comparison of students' attitudes by area of choice in relation to the question categories used previously is presented in Figure 3. The comparison will be based on 0.75 score intervals.

First, S students have the highest percentage on the [3.25 to 4] interval in all 4 categories, specifically with 77.24% and 90.24% in the decision and individual interest respectively.

A big difference between the students in relation to the interval score [3.25; 4] is found in decision and self-efficacy. For example, for OSE and L students, 38.64 and 8.82 for decision and 11.54 and 10.29 for self-efficacy respectively, therefor OSE and L students are about half the percentage of S students at this level. It is also important to mention that there are 13.24% of L students who score low in the decision category specifically in the range [1;1.75[, whereas this level other categories of students have higher decision scores. Similarly, in regards to individual interest, the scores are [2.5; 3.25[for all students, which can be interpreted as a good attitude towards the content of science. Regarding situational interest, the score is higher for S students in general, while for L students, there are 11.76% of students score between 1.75 and 2.5 which is the lowest score at this level.

In conclusion, among the three domains, S students have the highest score in general, especially in decision and self-efficacy

Figure 3. Recapitulation of student's attitudes in Natural Science (life and earth sciences) per field choices in percentage.

Performance in pre-test

The performance test highlights the ability of students in relation to Bloom's taxonomy. The percentage of average scores by question category is shown in Figure 4. In general, the average total score is less than 35% for all students, which can be interpreted as a low score on the pre-test. We have also seen that the best results are found in the knowledge questions and the poor results, below 10%, are observed in the higher levels of the taxonomy such as evaluating and creating. However, S students perform slightly better than others, especially in the applying questions, with difference 16.52% and 11.31 % with L students and OSE students respectively. Applying skill seems important for influencing students to choose Scientific field.

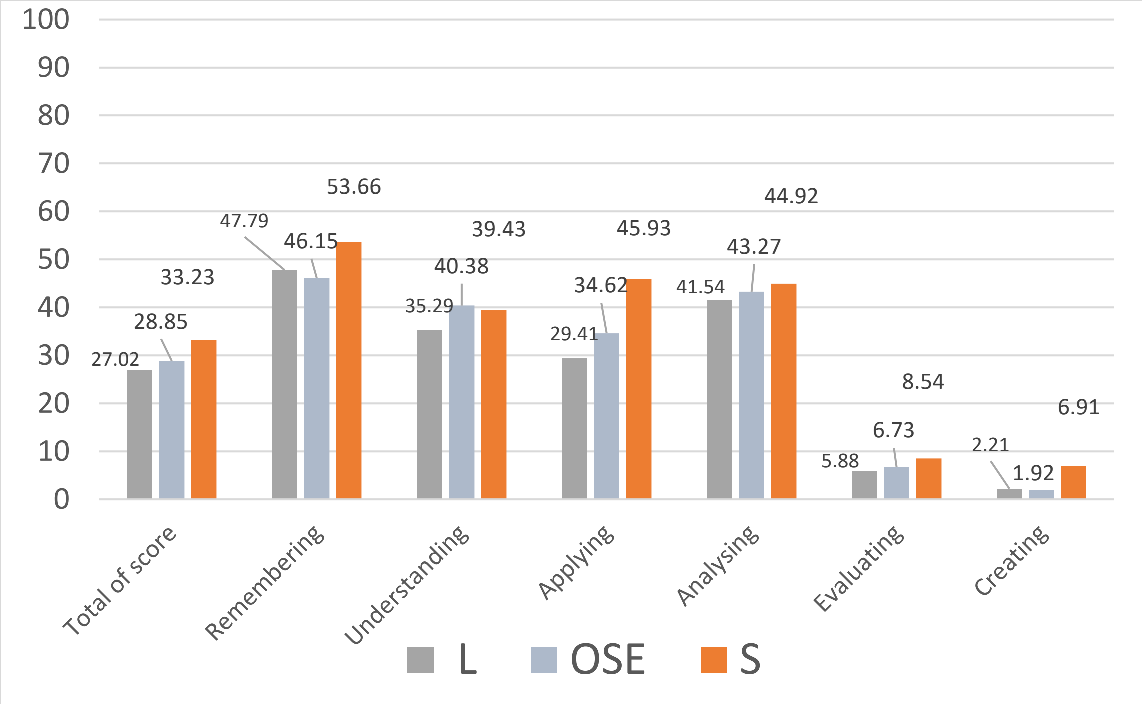


Figure 4. Performance score per category of questions and field choice in percentage (pre-test)

The comparison of the total average score by the school and by field choice is represented in Figure 5. Graphically, for S students, we observe that the peak, in general, is between 20 and 40% with the right-skewed distribution.

Indeed, the shape of the distribution of the score by choice of field is quite similar for each school with a higher score observed in school A. On the other hand, a large percentage of the score is observed among S students in school A. We conclude that a higher score is seen in school A specifically for S students.

To summarize this part, students who are predisposed to follow scientific field have higher score in performance, especially in remembering and applying. Additionally, a variation of performance is also found per school. The school in suburban area (school A) compared to the one in rural area (school B) has higher score.

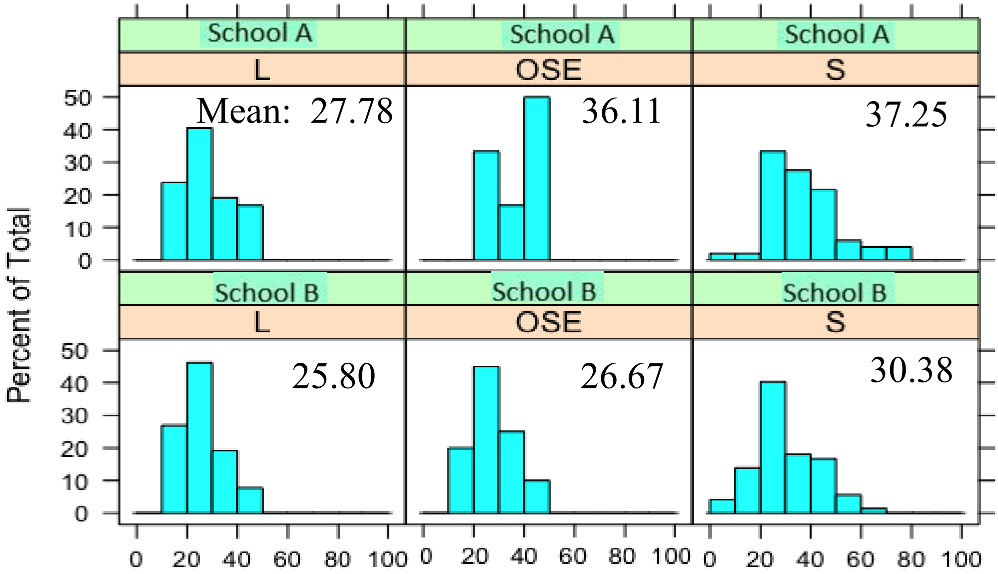


Figure 5. Histogram by groups: school, field choice, and mean of performance total score in percentage

Multiple regression analysis (using data from pre-test)

In multiple regression, the value of the dependent variable is influenced by two or more external factors, which are represented by the following formula (Indeed Editorial Team; 2022):

$Y = b0 + b1X1 + b2X2 + ... + bpXp$

In this equation, Y stands for the dependent variable or predicted value, which will be the decision factor in our study.

The variables (X1), (X2), and so forth (Xp) reflect the predictive values, or independent variables, that affect Y. It is critical to remember that each X factor represents a distinct predictive value. In our study, the variables will be the following factors: situational and individual interests, self-efficacy, and performance factors using the values taken from pre-test. The results from R are presented in the table.

Table 1. Results of multiple regression analysis

Residuals:

Min	1Q	Median	3Q	Max
-1.76770	-0.36394	0.07613	0.38756	1.49766

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-1.65833	0.47052	-3.524	0.000520	***
Self-efficacy	0.63438	0.10088	6.288	1.8e-09	***
Individual interest	0.38618	0.14374	2.687	0.007790	**

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Situational interest   0.46618    0.13632   3.420 0.000752 ***
Performance          -0.02151    0.07655  -0.281 0.778951
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Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
Residual standard error: 0.5566 on 212 degrees of freedom
Multiple R-squared:  0.3966,        Adjusted R-squared:  0.3852
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F-statistic: 34.84 on 4 and 212 DF, p-value: < 2.2e-16

According to this result, the multiple regression with four predictor variables (x) and predicting variable (y) is present in the following equation:

$Y= 0.63x +0.38 x_1+ 0.46 x_2 -0.02 x_3-1.65$

With Y: Decision factor, X: Self-efficacy factor, X1: Individual interest factor, X2: Situational interest factor, X3: Performance factor.

Considering the non-significance of Performance factor following the result in P-value 0.778951, we will have the following equation.

$\mathbf{Y= 0.63x +0.38 x_1+ 0.46 x_2 -1.65}$

Multiple linear regression assumes that the residual variable error is the same at each point in the linear model. This is referred to as homoscedasticity. This means that the prediction error does not significantly alter the expected prediction range. As a result, the residuals in our result are largely centered around zero and have a small similarity gap between them (median 0.07, minimum and maximum -1.76 and 1.49), indicating that the model is probably consistent with the heteroscedasticity hypotheses.

Furthermore, by comparing the estimated value of all variables, we can see that self-efficacy (X) and situational interest (X2) have the highest values. We can interpret, for our sample, that for every 1% increase in self-efficacy, there is an associated 0.64 increase (with a standard error of 0.10) in the decision, and for every 1% increase in situational interest, there is a 0.47 increase (with a standard error of 0.14) in the decision.

The Pr(>|t|) or P-value of the T-test also shows a very low value ($p<0.001$) for situational interest, individual interest, and self-efficacy that likely influence the decision.

Considering the variable Performance with a regression of estimates of -0.02, we found a low T-test value of 0.07 and a high P-value of 0.78, we can say that our performance test has no significant influence on the decision.

R-Squared is viewed as the proportion of the variance of the dependent variable that can be accounted for by the independent variables. Consequently, the model features may account for 0.3966 or 39.66 % of the target variation. As it ranges from 25 to 50%, we may say that our model explains a relatively tiny amount of variance.

B) The effect of HEC approach

Interests related to natural sciences

A comparison histogram of the students' interest levels before and after the intervention is shown in figure 6. First, we can see that the histogram of the particular interest is left-skewed and there are no obvious differences in the distribution between the pre-and post-intervention periods. From 3.23 mean to 3.45 mean, the distribution of situational interest increases to a higher score. The illustration for situational interest shows that there is some observable improvement while individual interest shows no change.

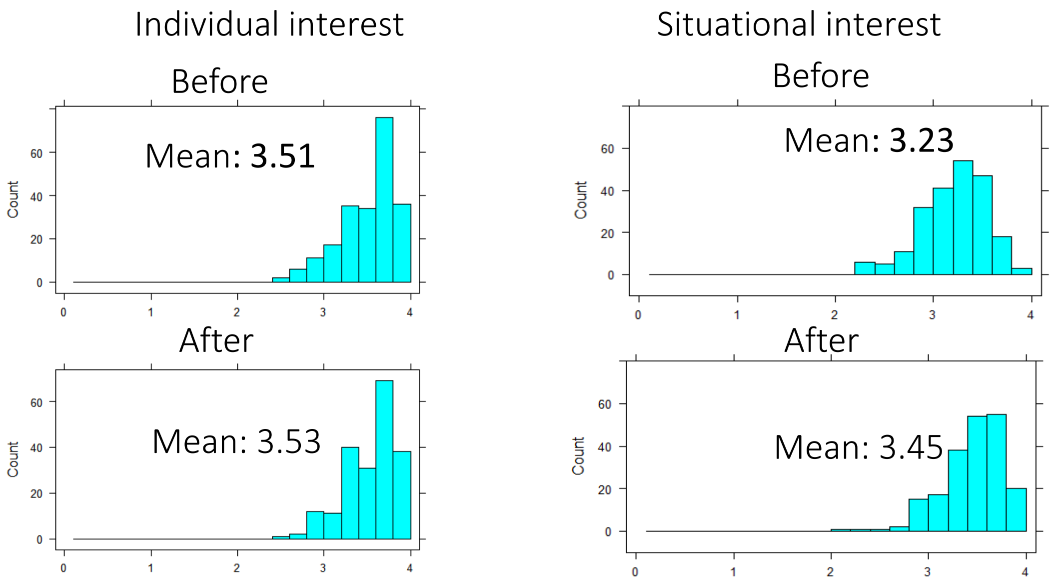
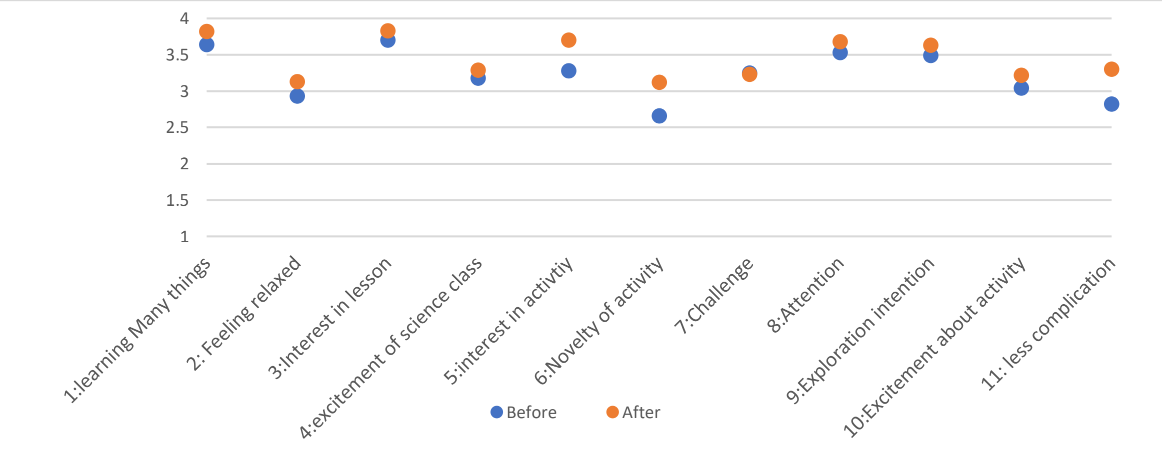


Figure 6. Comparison of two types of interest between before and after intervention

According to statistics, we discovered a significant difference in situational interest with P(T<=t) = 2.98E-12 <0.05; therefore, we may deduce that as a result of our intervention, students' interest in science classes has significantly increased. Individual interest, however, did not greatly change. This indicates that the intervention had little impact on their interest in science.

As the situational interest only shows a significant result, the results of situational interest related-questions are examined to identify which has changed the situational interest result the most. The variations for each statement are shown in the Figure 7. The comparison is done between students' class and activity with HEC with their usual class and activity. We observe a significant difference in the activity's novelty, interest, and degree of simplicity. Considering this result, the HEC method makes the task more interesting, particularly because it is unique and less difficult. However, we can observe that the challenge statements are still the same. The method's implementation does not appear to raise the challenge level.



Legend

1.I learn many things in our science class
2.I feel relaxed in our science class
3.I don't find anything interesting in our science lessons (those who are disagree)
4.Compared to other subjects, our science class is exciting to me
5.The activity is interesting,
6.This activity is new to me
7.This activity is a demanding task
8.My attention was high
9.I want to discover all the tricks in this activity (exploration intention), and
10.This activity is exciting
11.The activity was complicated (those who are disagree)

Figure 7. Comparison of the student's average score for each statement between class and activity held during pre- and post-test

Performance

Presently, treating graphical and t-test analysis, the evolution of performance is examined. Therefore, Figure 8 displays the distribution of the student's scores. The distribution before the intervention is right-skewed, as seen by the score percentage histogram. As a result, the majority of students started with scores between 0 and 40, with the median which is about 50 students scoring about 20%. After the intervention, the distribution physically changes, with the majority of students receiving scores between 40 and 60 and a median of roughly 50% with 50 students. It draws attention to how the score has improved.

In addition, a two-sample t-test assuming equal variances shown in the table adjacent to the picture after the F-test.

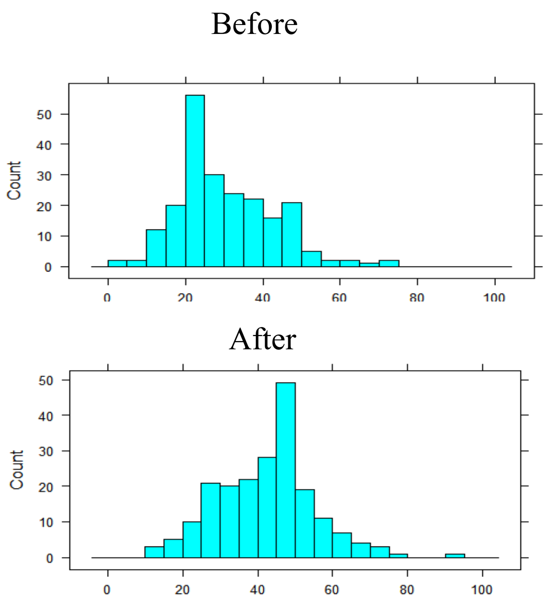


Figure 8. Comparison of student's performance before and after the intervention in percentage

The mean rises from 30.76 to 42.58, as can be seen. Since the significant difference is confirmed by the two-tailed P-value of 1.49E-19 <0.05, we may conclude that the student's performance has massively improved.

Figure 9 now depicts the progress by question category. It is obvious that student growth has increased dramatically overall, with more than 20% growth in knowledge, more than 14% growth in analysis, and 11% growth in synthesis.

In conclusion, Students' abilities in higher-order logical reasoning, such as analyzing and creating, could be enhanced slightly by the method. This is related to the presence of a task where they can test their hypotheses and record their findings, as well as a task where they have a higher probability of relating their life-long learning to the current task.

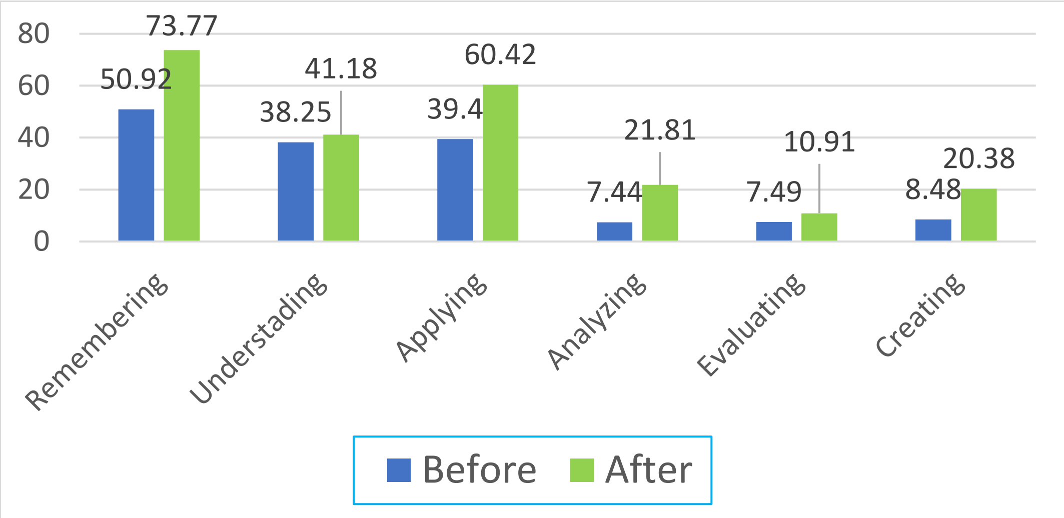


Figure 9. Evolution of performances per question categories

Others finding

It is important to report that their decision score was not changed by HEC with P (T ≤ t) two-tail:0.16 >0.05. It is assumed that the decision may take longer for a significant change. Furthermore, since self-efficacy was found to be correlated with the student's decision, as stated above, this may be a reason that self-efficacy did not improve also. Indeed, self-efficacy, which averaged scores across all questions ranging from 3.03 to 3.10, did not improve statistically. Their performance beliefs did not increase with the HEC. We can say that they are still unsure of their performance in the natural sciences.

4) Discussion and conclusion

With regard to the low participation in science in high schools in Madagascar, this research investigates the reason for this demotivation and the effectiveness of HEC in promoting interest and performance in natural science subjects.

Some of the traits seen in students who selected scientific option included the following.

– Regarding the students' attitudes toward the subject of natural science, it appears that, in comparison to the other students, those who choose to follow scientific studies have greater levels of individual interest, situational interest, self-efficacy, and decision-making toward natural science. Students who are interested in studying scientific options have the best attitudes toward natural sciences. Most importantly, there was a significant difference in self-efficacy, with 44.72% of S students obtaining the highest score [3.25; 4], whereas L and OSE students only achieved 10.29% and 11.54%, respectively. After that the regression analysis where the decision making was the dependent variable and the other factors (individual interest, situational interest, self-efficacy and performance) are the independent variables shows that self-efficacy had the highest regression coefficient (0.63 %). This finding confirms our previous statements regarding the importance of self-efficacy. We can say that attitude, particularly self-efficacy, has a close relationship with decision making.

This is consistent with our initial results in 2021; most students did not enroll in the scientific field, mainly because of their poor perception of their performance (Raveloson, 2021).

– For the performance test (before HEC intervention), it was found that students who intend to go to the scientific field have a slight difference in performance with other students, especially in the application ability, with a difference of 16.52 score and 11.31 score with L and OSE students, respectively. However, in terms of total scores, there was a difference between S and L students, with a higher score for School A, which is located in suburban area.

We can infer that the performance was different among the 3 groups of the students (L, S and OSE).

There is some variation according to locality also; the average score seems to be higher in suburban areas compared to the school in rural areas.

– Effects on student attitudes

After using the HEC method, there was a large improvement in situational interest from 3.23 to 3.45, with a t-test score of $P(T<=t) = 2.98E-12 < 0.05$. After examining each question in the situational interest question category, a change in the mean for the following criteria was observed graphically: interest in the activity, less complication, and novelty of the activity, the latter being the lowest score found in the pretest. Students seemed to enjoy the activity primarily for novelty and less difficulty. HEC method enhances students' situational interests much more than individual interests. This could be due to the large difference between HEC and their normal classes. This could be a consequence of restrictions related to the learning environment such as materials and over crowdedness. Indeed, we believe that the increase observed in situational interest is already an important achievement because, according to Chen and Darst (2002), situational interest motivates engagement in learning. As shown in Harackiewicz's conceptual model in 2016, interventions such as problem-based learning work in interest, which will later provide an outcome related to the future plan. The process of change in outcomes seems to go step by step and it goes through the increase of situational interest, which will be a step to strengthen engagement in science. These results also confirm the conclusion of a researcher from Gulfan (2020) on the increase of the student's interest, especially the pleasure of the activity, with an increase of about 6 to 56% and 0 to 77% for the two experimental sections, and a positive result on the statements related to the love of science and the impatience for the next science class.

– Effect on performance

The average total score increased significantly, from 30.76 to 42.58%.

Regarding the cognitive domain in relation to the level of the questions, remembering ability improved the most. We also observed improvement in applying from 39.4 to 60.42 %. Some improvements are seen also in analyzing (7.49 to 10.91%) and in creating (8.48 to 20.38%).

This agrees with Holbrook and Rannukmae's theory in 2007 that the activity using concepts dealing with socio-scientific issues works in developing skills such as creativity and initiative; and it also develops a positive attitude and contributes to enhancing students' social value and undertaking science-related careers.

In general, interest and performance, especially self-efficacy in the natural sciences, are important factors in encouraging students to choose a science option. Students are likely to choose scientific options when they feel confident. However, even if self-efficacy did not directly improve after the implementation, the HEC technique had a significant effect on situational interest and performance. It is expected that these facts will ultimately lead to an increase in each person's individual interest and help students feel confident and successful, which may impact their enrollment in scientific options. Subsequently, we suggest an HEC approach to natural science subjects using new activities and clear instructions.

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