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# Comparison of Traditional-Classroom Instruction and Inquiry Based Science Education (IBSE): a Preliminary Study of Students' Perceptions

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## Abstract
*Over the past few years the students' decline of interest for scientific studies and careers has led several countries to account the achievement of the standards of learning as the most important priority.*
*A key factor for improvement could be the dissemination at school of new instructional models such as Inquiry-based Science Education (IBSE), focused on active learning. Inquiry-based learning comes from constructivist theories. It is an instructional model that centers learning on addressing a particular problem or answering a central question. This means that students learn to construct their own understanding through the reflection on their experiences, based on hands-on activities, focusing on both the contents and the processes of science.*
*This study focuses on analyzing high school students' perceptions about the implementation of IBSE approach in classroom, with the objective to investigate the impact of IBSE, compared to the traditional approach. The preliminary part of the study is addressed to validate a questionnaire which is developed with the collaboration of experts in statistics. The validated questionnaire is then used in a broader survey, now in progress, focused to measure and compare the effects of IBSE and traditional instructions on students' school achievement.*
*The new perspective of this study, compared to previous studies, is that the questionnaire has been built in order to elucidate key aspects of both inquiry-based and traditional instructions, in a way that students can compare the two different approaches.*
*The study involves 87 participants from two high schools. All the participants are students whose teachers took part in the SID (Scientiam Inquirendo Discere) Programme. This programme is a systemic model for IBSE implementation in Italy that provides teacher professional development by their participation to training courses, to supporting actions in presence and on line and by the development of didactic resources.*
*Although the study is in progress, it already showed students' perceptions, assessment of motivation and engagement, bringing out strengths and weaknesses of the two approaches. Statistical analysis in data processing was used for a descriptive study. In particular, the t-test and p-value analysis indicated that 26 out of the 36 survey items received statistically different answers. Results showed that in general students gave positive evaluations to their experience with IBSE activities, considered them a successful teaching/learning process, recognizing the value of good practices. These results are more evident among female students, among students from higher socio-cultural level, as well as among those scoring good marks. On the other hand, students did not perceive to achieve a deeper knowledge by IBSE than by the traditional learning and they did not consider IBSE an effective approach for their future careers.*

## 1. Introduction
Nowadays students are not achieving scientific literacy, with a decline of interest in science contents and scientific careers. The opportunities for progress at the higher educational level have to bring about new crucial considerations on teaching and learning. A growing interest in changing is suggested by official European documents: "Rocard Report" [1] and a new report from the Expert Group on Science Education (June 2015) [2] suggest a reversal of school science-teaching pedagogy from mainly deductive to inductive; inquiry-based methods provides the means to increase interest in science.

Recently, many European projects has been created shifting the attention from "what" is learnt to "how" it is learnt, looking at different learning methods, mostly student centered. Inquiry Based Science Education (IBSE) has become one of the most prominent alternatives to traditional science education.
Also in Italy, in 2011, a systemic model for IBSE implementation, *Scientiam Inquirendo Discere* (SID) Programme [3], has been developed. It provides teacher professional development by their participation to training courses, to supporting actions in presence and on line and by the development of didactic resources.

### 1.2 Background

Inquiry-based learning is an instructional model that centers learning on addressing a particular problem or commenting a central sentence: "*At the heart it is an active learning in which students answer research question through data analysis*" [4]. There are several different inquiry-based learning models, but most have these general elements in common [5] :i)students conduct investigations or collect data by themselves; ii) they can use evidence to decide what works and what does not work, to contribute to the understanding of the world around them. As well as building understanding, they are also developing skills such as critical thinking, communication skills and the ability to learn both independently and collaboratively. Moreover, IBSE is not only focused on content or hands-on activities. It also shifts the focus on the acquisition of skills as defined in constructivism educational approach.
Numerous studies demonstrated that a student's active involvement in the learning process enhances learning. Most of these studies were explorations of the perceptions of all stakeholders regarding scientific inquiry, nature of science, and pedagogical approaches, and assessing the effectiveness in increasing students' interest in science [6]. A few numbers has been carried on in Italian schools.

### 1.3 Research Focus

The goal of this study is to better understand students' perceptions of the effectiveness of these two educational paradigm: IBSE and the traditional approach. It is a part of a broader survey, now in progress, focused on measuring and comparing the effects of IBSE and traditional instructions on students' school achievement.
In addition, the significance of this research is closely connected with the evaluation of the efficacy of the inquiry-based approach promoted during the SID Professional Development programme. It is a further contribute to understand how students perceive their science experiences when their teachers develop curriculum and design instruction that promotes students' science learning [7], acquired attending SID courses.
The preliminary part of the study is addressed to validate a questionnaire, which has been developed with the support and supervision of statistic experts from Sapienza University, Rome.
In a new perspective, the questionnaire has been built in order to elucidate key aspects of both inquiry-based and traditional instructions, in a way that students can compare them.
The data collection and subsequent analyses were guided by the following research questions:

- What are the students' perceptions on key elements of instruction?
- Which are considered effective?
- Does the individual and social context influence the results?
- Is it possible to measure a significant difference in students' motivation between the two approaches?

## 2. Method

The study followed a quasi-experimental research methodology with a non-random selection of participants. It describes the students' perceptions on their own science experiences through inquiry. It involved 87 students (14-15-16 years old, 53 girls and 34 boys) in two high schools (one urban and one suburban) and their respective 3 science teachers, all involved in the SID Programme held at Rome SID Pilot Centre, in 2014/15. Each teacher chose one didactic unit among those she/he tested during the SID course, she/he developed it in classroom, according to the inquiry approach and then she/he voluntarily accepted to participate in the study with the students. The classroom implementation was carried out from January to March 2015. The research data were collected through a semi-structured questionnaire. It was designed in part based on the questionnaires for

students used in previous studies [8, 9] and used in European projects aimed to promote the innovation of Science Education [10]. It represented a pilot test in order to establish internal consistency of the instrument, for its use in the broader survey. Each item was designed to measure the students' perception of instruction as consisting of traditional or nontraditional practice. It was made up of three sections that considered two constructs: awareness and evaluation of instruction. In **Section 1** the personal data were included as well as the school and class attended, and the science marks (1-6 items). **Section 2** concerned the analysis of the instruction key elements used in classroom: it would measure how much students were conscious about the differences between the two approaches. **Section 3** concerned the evaluation of effectiveness of each step of the activities: it would measure what elements were evaluated effective by students for their learning.
Each item was administered to each student twice, one for analysis of IBSE approach ("A") and one for the traditional approach ("B"). Students were required to rate each item on a 10-point Likert-type scale ranging. For each item, data were expressed as average of within-student differences between IBSE and traditional scores. Paired t-test was used to test the null-hypothesis of equivalence between approaches.

## 3. Results

The following table summarizes the average of differences of students responses in 15 items of **Section 2** (Table.1) and 21 items of **Section 3** (Table.2). They show the average values of the corresponding responses by boys and girls, students with graduated parents, with high or low marks and students who have already used the IBSE approach or not, in order to evaluate the influence of different variables, mentioned in previous studies [6], about science knowledge and motivation, such as gender differences, urban and suburban schools, previous involvement in inquiry, parents' cultural level.

| | | All | P-Value | Girls | Boys | Low marks | Medium marks | High marks | Graduate | No graduate | Younger | Older | Urban | Suburban |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Section 2 | | | | | | | | | | | | | |
| a | You used the textbook | -4,15 | 2,2E-16 | -4,53 | -3,56 | -2,17 | -4,64 | -4,80 | -4,51 | -4,93 | -3,64 | -4,62 | -3,81 | -4,23 |
| b | You learnt the subject contents | -0,01 | 9,5E-01 | -0,09 | 0,12 | 0,28 | -0,20 | 0,60 | 0,07 | -0,29 | -0,05 | 0,09 | 0,69 | -0,17 |
| c | You learnt science facts finding out them in lab | 2,39 | 1,0E-10 | 2,83 | 1,71 | 1,44 | 2,41 | 4,00 | 2,38 | 2,50 | 1,82 | 2,94 | 2,94 | 2,27 |
| d | You learnt science facts | 1,49 | 3,7E-06 | 1,74 | 1,12 | 1,06 | 1,44 | 2,60 | 1,56 | 1,71 | 0,92 | 2,04 | 2,19 | 1,34 |
| e | You learnt from classmates | 0,90 | 4,0E-03 | 1,47 | 0,00 | 1,22 | 0,66 | 1,70 | 1,11 | 0,79 | 0,18 | 1,53 | 0,44 | 1,00 |
| f | You learnt how science is part of real word | 0,69 | 6,0E-03 | 0,23 | 1,41 | 1,78 | 0,08 | 2,30 | 0,84 | 0,43 | 0,33 | 1,04 | 2,06 | 0,38 |
| g | You learnt history is crucial for understanding concepts | 0,08 | 7,3E-01 | -0,04 | 0,26 | 1,06 | -0,32 | 0,70 | 0,00 | 0,29 | -0,49 | 0,55 | 0,50 | -0,01 |
| h | Your teacher lectured | -2,21 | 1,305E-07 | -3,00 | -0,97 | -1,22 | -2,24 | -3,80 | -2,33 | -2,71 | -0,79 | -3,40 | -0,38 | -2,62 |
| i | You had a say in deciding what we do in class | 1,38 | 1,1E-05 | 1,32 | 1,47 | 1,11 | 1,19 | 3,00 | 1,55 | 1,50 | 0,79 | 1,91 | 2,38 | 1,15 |
| l | Your teacher did demonstrations | -0,48 | 1,3E-01 | -1,11 | 0,50 | -0,17 | -0,61 | -0,30 | -0,44 | -1,29 | -0,05 | -0,83 | 1,31 | -0,89 |
| m | You memorized information | 0,24 | 2,6E-01 | 0,04 | 0,56 | 0,83 | -0,05 | 0,90 | 0,31 | -0,07 | 0,64 | -0,04 | 1,56 | -0,06 |
| n | You worked alone | -2,47 | 8,9E-09 | -2,98 | -1,68 | -1,22 | -2,78 | -2,90 | -2,76 | -1,64 | -1,49 | -3,34 | -1,38 | -2,72 |
| o | You worked in groups | 3,14 | 6,9E-14 | 3,19 | 3,06 | 2,33 | 3,03 | 5,20 | 3,33 | 3,14 | 2,21 | 4,02 | 3,56 | 3,04 |
| p | The class had debates about science topics | 0,87 | 9,3E-05 | 1,00 | 0,68 | 0,33 | 0,93 | 1,50 | 0,98 | 1,29 | 0,56 | 1,17 | 1,25 | 0,79 |
| q | Students respected one another | 0,98 | 9,3E-05 | 0,92 | 1,06 | 0,83 | 0,88 | 1,80 | 0,78 | 1,93 | 0,46 | 1,47 | 0,81 | 1,01 |

Table 1: **Section 2- Awareness**: average of within-student differences between IBSE and standard lecture scores of instruction key elements (in red inch not significant values:p>0,05);

As seen in **Section 2,** there is a statistically significant difference between the two approaches in 11 out of 15 items. All items related to inquiry learning have high value of difference; the most were: *working in groups* (o), *learning in lab activity* (c), with stronger differences for students with high marks and not beginner with the IBSE.
Students are aware that the new approach requires less use of the textbook that is fundamental in the traditional approach, less lectures teacher, less individual and more group work with classmates. Significant differences also for other peculiar aspects of IBSE (d, e, i, p, s, q): learning science facts (d), peer learning (e) participation in decisions (i) discussion of scientific topics (p) and respect for each other's opinions (q), with more awareness in students with high marks and with graduated parents.
Items b, g, l, m are not statistically different: in both methods at the same way, students learnt contents (b) and the importance of the history of science (g), memorized information (m), their teacher did demonstration (l).
As seen in **Section 3** students were asked for an evaluation of the two approaches, responding to what degree they agree with the statements in the list. Results are reported as average of within-student differences between IBSE and traditional scores.
There is a statistically significant difference between the two approaches in 15 out of 21 items.

The items were divided into 5 categories according the kind of activities and the quality of teaching-learning process.

| Categories | Items |
|---|---|
| 1. Student-centered activities | b,d,e,g,l |
| 2. Individual engagement | a, c,f,n,o |
| 3. Lab activities | h, i |
| 4. Teaching-learning process | m,t,u,v,z |
| 5. Usefulness in the future | p,q,r, s |

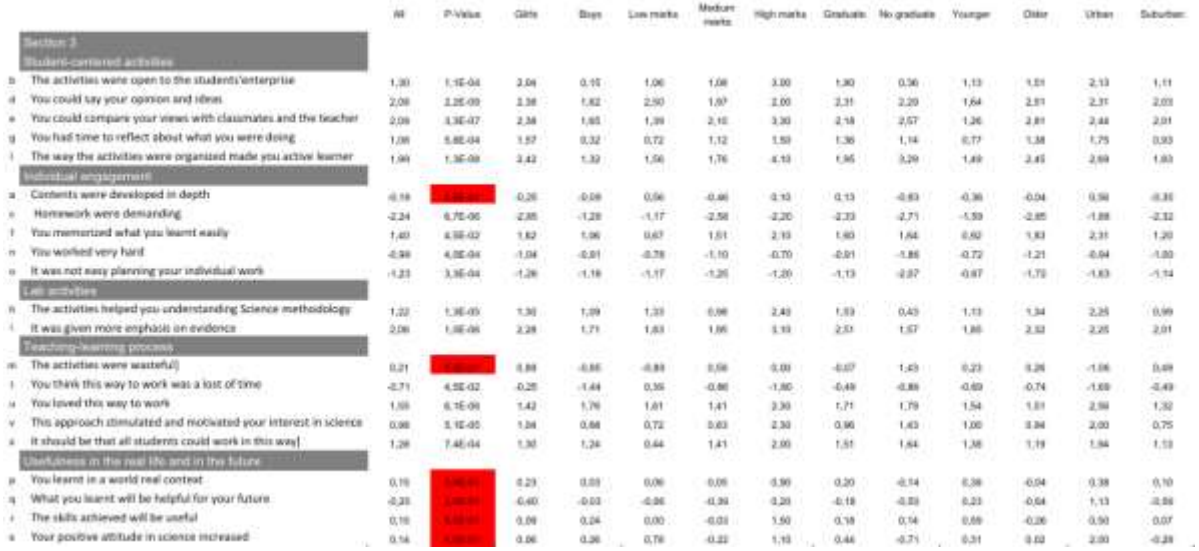

Table 2: **Section 3 - Evaluation**: average of within-student differences between IBSE and standard lecture scores (in red inch not significant values:p>0,05)

1. Items in 1st category have high rating (7,1<rate<8,2) for IBSE approach, with significant difference in the comparison between the two approaches. This is more evident in students with high marks, from suburban school, and in girls.
2. In the 2nd category, individual learning is considered in general easy (with rating lower than mean), and easier in inquiry than in traditional instruction; items are significant except "content learnt in depth" (a).
3. Rated 7,6 and 7,1 items about lab activities in inquiry and lower rating in traditional approach.
4. The degree of appreciation of IBSE is 7,6 versus 6,1 in traditional instruction; there is a significant difference even if both approaches were evaluated with a good score; the highest difference is given by students with graduate parents.
5. Items related with the future benefits to using inquiry or traditional approach are not significantly different, although the rate is close to 6.

## 4. Discussion

Although the study is in progress, it already showed students' perceptions, assessment of motivation and engagement, bringing out strengths and weaknesses of the two approaches. In particular, the paired t-test analysis indicated that 26 out of the 36 survey items received statistically different answers. Student centered activities are thought as features of IBSE instruction and appreciated by students. Results showed that in general students considered inquiry experience a successful teaching/learning process, recognizing the value of good practices. These results are more evident among girls, among students from higher socio-cultural level, as well as among those scoring good marks. There is an overall positive rating of teaching-learning process, with higher rating for IBSE instruction.

Otherwise, students did not consider their knowledge to be deeper through IBSE than the traditional learning, maybe because of their teachers, who were involved in SID course, have a high professionality and their teaching was already good. In addition, students found difficult to switch completely the methodology as the environment and school context is still very traditional.

Moreover students were not aware that IBSE could be an effective approach for their future careers and they did not consider that it could give gains.

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