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Learning Micromanipulation, Part 1: An Approach Based on Multidimensional Ability Inventories and Text Mining

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Abstract: In the last decades, an effort has been made to improve the efficiency of high-level and academic education players. Nowadays, students' preferences and habits are continuously evolving and so the educational institutions deal with important challenges, such as not losing attractiveness or preventing early abandonment during the programs. In many countries, some important universities are public, and so they receive national grants that are based on a variety of factors, on which the teaching efficiency has a great impact. This contribution presents a method to improve students commitment during traditional lessons and laboratory tests. The idea consists in planning some activities according to the students' learning preferences, which were studied by means of two different approaches. The first one was based on Gardner's multiple intelligence inventory, which is useful to highlight some peculiar characteristics of the students on the specific educational field. In the second method, direct interviews, voice recognition, and text mining were used to extract some interesting characteristics of the group of students who participated in the projects. The methods were applied in May 2018 to the students attending the course of Micro-Nano Sensors and Actuators for the postgraduate academic program dedicated to Industrial Nanotechnologies Engineering of the University of Rome La Sapienza. The present paper represents the first part of the investigation and it is dedicated essentially to the adopted methods. The second part of the work is presented in the companion paper dedicated to the presentation of the practical project that the students completed before the exam.

Keywords: teaching; learning; mocromanipulation; microactuation; multiple ability inventories

1. Introduction

Teaching methods and procedures at the high level of education and in Academia have been changing during the last years, whereas improving the efficiency of the educational process has become a crucial target for institutions [1,2]. Related studies show that improving the teaching–learning process has a certain impact on economic development [3], while the process itself is ineluctably affected by the mutual influences between technology and society [4] and by socio-emotional issues [5].

Furthermore, in many European countries, recent laws apply rewarding criteria to those institutions who support innovation in teaching and reduce the number of students abandoning or prolonging their courses.

In this paper, a recent experience of teaching–learning activities is presented, with the purpose of suggesting a way to improve students involvement and achievements. The adopted methods were applied in May 2018 to the students attending the course of Micro-Nano Sensors and Actuators for the Master degree in Industrial Nanotechnologies Engineering of the University of Rome La Sapienza. The present paper is dedicated essentially to the description of the teaching methods, whereas the consequent students' activities are presented in its companion paper [6].

An Approach Based on Multidimensional Ability Theoretical Framework

The basic idea for this investigation consisted in detecting the students' learning preferences and then tailoring some activities that could match the detected learning styles. This approach was expected to have the maximum effect in terms of achievements and satisfaction. The detection of the students' preference profile was approached by means of two different methods. The first one was inspired by the concept of Multidimensional Abilities, while the second one was based on text analysis.

Multidimensional Abilities have been investigated through well-known theoretical frameworks:

- Aptitude-Treatment Interaction [7];
- Conditions of Learning [8];
- Dual Coding Theory [9];
- Multiple Intelligences [10];
- Structure of Intellect [11]; and
- Triarchic Theory [12].

In this study, Gardner's approach was preferred because it has been applied in the past and gave some interesting results (see, for example, [13–16]). According to the original formulation of Multiple Intelligence inventory, the following intelligences are considered:

- Intrapersonal;
- Bodily-Kinesthetic;
- Interpersonal;
- Logical-Mathematical;
- Spatial;
- Verbal-Linguistic; and
- Musical.

Nowadays, Gardner's Multiple Intelligence is very popular and its principles have been described in many reference books and websites. In the present investigation, this inventory was applied to the specific context of learning in a technological education field, micromanipulation, in a high-level academic course. Consequently, the investigation must be considered as restricted to a rather superficial layer of one student's individual personality. The results do not concern the individual's general characteristics, but rather involve the individual's characteristics in the context of the specific environment, namely, a course in Industrial Nanotechnologies Engineering. To better explain this concept, let us review how the multiple intelligences have been applied in the context of learning in the academic environment.

Intrapersonal intelligence was not measured as an individual's general characteristic, but as a student's attitude of thinking and studying alone, without external interactions.

Bodily-Kinesthetic intelligence was associated with the use of practical activities that involve manual handling of models or instruments in a lab. This attitude was also associated with the use of physical support for studying and understanding.

Interpersonal intelligence was here related to some students attitude to gain benefit from social activities, such as studying in the company of other people and participating or promoting small social events.

Logical-Mathematical intelligence was associated with the students' preference for using logic and mathematical formulation to understand new models and concepts.

Spatial intelligence was related to a student preference for using graphical tools, such as pictures, diagrams, block charts, or spatial models.

Verbal-Linguistic intelligence was related to the students' preference of learning by reading or hearing some text.

Finally, Musical intelligence was measured as in standard tests but was not related to any dimension for the sake of the present investigation.

2. Material and Methods

A questionnaire was submitted to a limited group of students to measure their singular preference profiles based on Gardner's inventory. The adopted test has the advantage that it has been used before [16] on a reference group and on some groups of students enrolled in the courses of Engineering at Sapienza University. Therefore, averages and standard variations on raw scores were already available for the adopted dimensions. This circumstance was quite important because the number of participating students was rather limited ($n = 6$).

2.1. Correlation Analysis among Dimensions

As for the previous investigations [14–16], standard statistical analysis was applied to the raw scores obtained from the surveys. Then, standard z-scores were calculated by an elementary routine. z-scores are a standardization of the raw data which maps scores in such a way that the standardized population has a null mean and a unit standard deviation (see Figure 1).

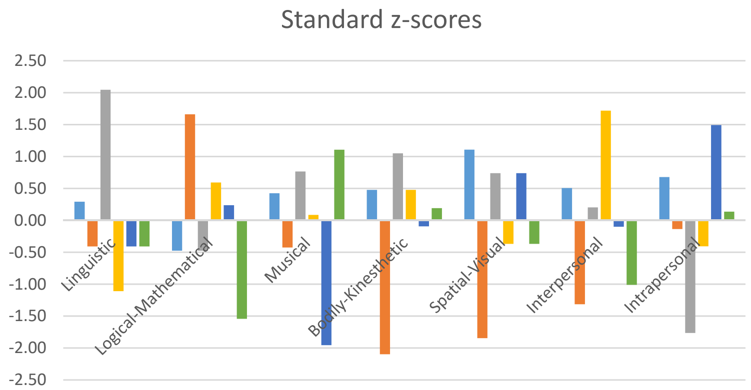

Figure 1. Individuals standard z-scores for the adopted seven dimensions.

The adoption of the z-scores was useful because the calculation of the correlation matrix becomes quite easy. Table 1 shows the classical correlation table for the seven dimensions under analysis. Since only six individuals participated in the survey, the obtained results are not significant for possible generalization and so the curious positive or negative correlations have a value restricted to the analyzed group.

Table 1. Correlation table for the group of participating students ($n = 6$).

	Verbal	Logical	Musical	Kinesthetic	Spatial	Interpersonal	Intrapersonal
Verbal	1.00	−0.32	0.35	0.43	0.47	−0.06	−0.59
Logical		1.00	−0.57	−0.71	−0.57	0.01	0.03
Musical			1.00	0.39	−0.01	0.03	−0.63
Kinesthetic				1.00	0.81	0.64	−0.26
Spatial					1.00	0.47	0.15
Interpersonal						1.00	−0.14
Intrapersonal							1.00

Figure 2 shows the scatter diagrams which illustrate an example of both positive and negative correlations among two pairs of dimensions. As mentioned above, it is not possible to draw a general conclusion that any student who has a kinestetic preference must have necessarily a great spatial-visual attitude and a small Logical-Mathematical preference. This is only a trend that appeared in a small class.

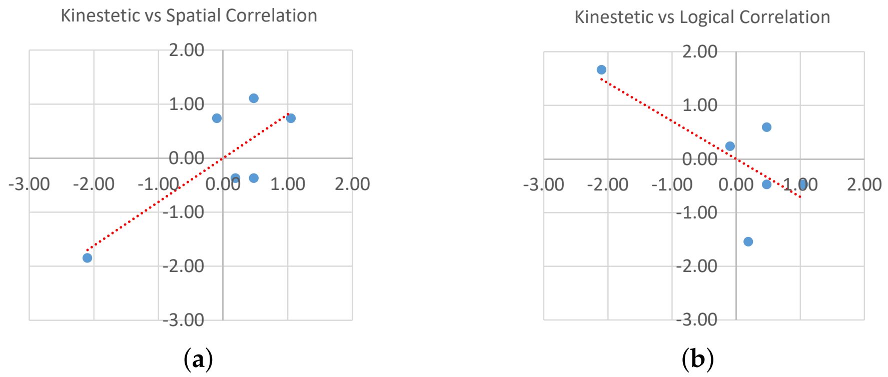

Figure 2. Scatter diagram for two pairs of dimensions: (**a**) Spatial-Visual vs. Bodily-Kinesthetic positive correlation; and (**b**) Spatial-Visual vs. Logical-Mathematical negative correlation.

2.2. Characteristics of the Class Group

The present investigation attempted to ascertain whether the small class was characterized by peculiar characteristics. Of course, this analysis must be done by comparing the dimensions averages of the class with those obtained in a control group. Fortunately, the same questionnaire had been previously submitted to a much larger control group during an earlier investigation [16], and so these results were used for the present analysis. For each of the seven dimensions, the pairs of averages were compared by pointing out those with a minimum value for the significance levels. Hence, the null hypothesis $\mathcal{H}_0$ was set as the assumption that the class and control groups were extracted from the same population.

Weak ($0.01 < \alpha \leq 0.1$) or strong ($0.001 \leq \alpha \leq 0.01$) probability levels were adopted together with Student t-test and the degrees of freedom $n_A = 6$ and $n_B = 56$ corresponding to class and control group populations, respectively. Some significant differences are reported in Table 2.

Table 2. Significant differences between raw score dimensions of the class and control group populations.

	Verbal	Logical	Musical	Kinestetic	Spatial	Interpersonal	Intrapersonal
p	lower >0.1 no	greater 0.025 weak	lower >0.1 no	greater 0.1 weak	greater 0.001 strong	greater 0.001 strong	lower >0.1 no

- Verbal (or Linguistic) Intelligence: According to previous investigations, students enrolled in high-level Engineering courses present verbal capabilities usually higher than their peers who

do not frequent Academic Institutions. Our class students present the same characteristic as the control group students, and therefore no significant difference was found for this dimension.
- Logical-Mathematical Intelligence: Our students showed a preference for logical and mathematical formalism weakly greater than the students belonging to the control group. This is quite reasonable for students enrolled in the last year of a master course in Nanotechnology.
- Musical Intelligence: No significant difference was detected for this dimension.
- Kinesthetic Intelligence: This dimension is characterized by a weakly significant difference in the average scores for the two groups; actually, engineering students are quite handy and so our students simply showed an attitude a little more pronounced than the control group.
- Spatial-Visual Intelligence: According to the significance analysis, it is quite sure that our students prefer an approach based on practical observation of planar schemes and 3D objects manipulation more than peers students enrolled in other courses; this dimension suggests the use of real objects and the practical manipulation of real models as an effective teaching method for this class.
- Interpersonal Intelligence: The clear preference in the class of an approach based on interpersonal intelligence is a straightforward suggestion to adopt interactive lessons with a considerable amount of teamwork.
- Intrapersonal Intelligence: No significant difference with respect to the control group was detected for this dimension.

3. Text Mining for the Identification of Patterns

Before the starting of the course, some interviews were arranged with the students. The transcripts of the oral interviews were automatically obtained by means of available software with the simple aid of a smartphone.

The following questions were submitted to the students before the beginning of the course.

1. Which is your personal motivation for you to study Nanotechnology?
2. What do you think about the activities in the lab?
3. What is your opinion about manual activities?
4. Do you think they can help your understanding of the lessons?

The following questions were submitted to the same students during of the course.

5. Did you change your opinion about the activities in the lab?
6. How much do you feel adequate for this experience in the lab?
7. What are your personal features that you think they are the most suitable for this experience?

These questions were used as cognitive stimulus to trigger the explication of concepts from the interviewees. The questions had the function of making some concepts more visible than in the case of a free speech. The advantage of this technique consists in the possibility of handling quantitatively some parameters of interest.

Then, the answers were filtered to remove from text some insignificant part of the spoken language and to obtain a polished text (conjunctions, prepositions, articles, and so on). The latter was then analyzed using text mining classification and frequency analysis of words occurrences. The graphic technique of words cloud was applied to extract key concepts and the most used words, and a graphic composition of such collection is reported in Figure 3, where dimensions and colors are related to the occurrence frequency. This wordcloud representation is very interesting to gain a picture of the tags that were most raised during the conversations with students.

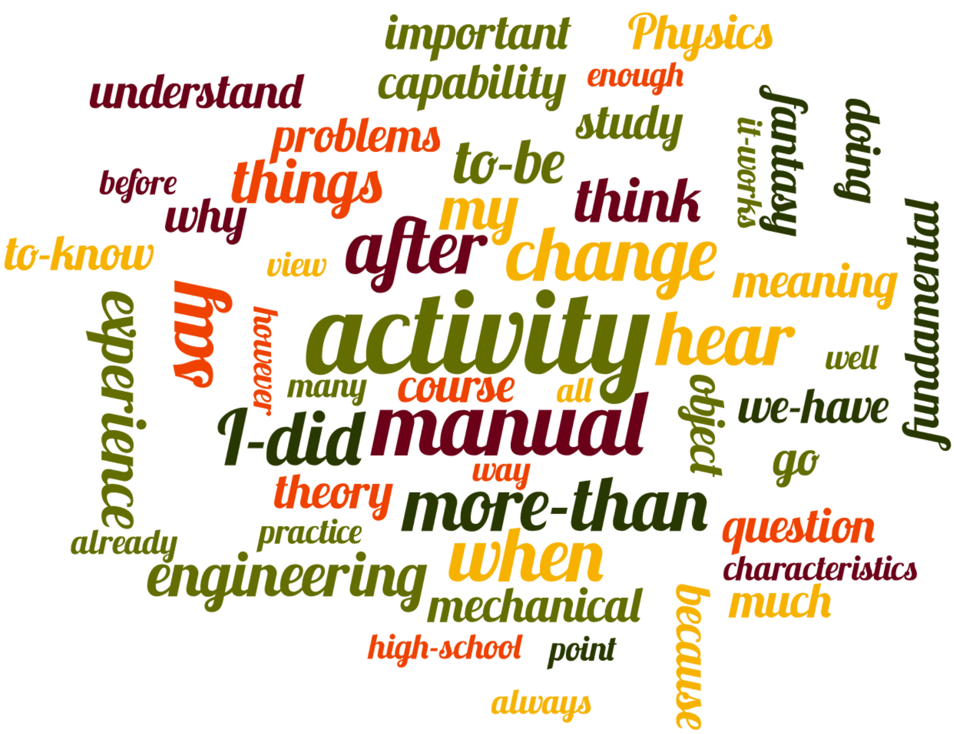

Figure 3. Most frequently mentioned words during interviews.

The following are some examples of frequently spoken words during the interview (see also Figure 3), and some reasonable interpretations.

- activity, experience, things, practice, hand, it-works, manual, and doing: These words are quite central during the interview; they are related to the students direct involvement to the lab activities and their willingness to learn by means of direct experience rather than by means of the classical textbook study.
- view and hear are also related to senses and so to the experience.
- more than, when, after, before, change, and go: These words are clearly related to time, development and progress and therefore they show the students willingness to improve, compete and face challenges.
- engineering, mechanical, Physics, high school, and study: These are clearly related to the context of the course.
- think, understand, meaning, fundamental, and important: These are related to cognitive and learning process.
- my and I-did: These are probably related to the students positive self promotion, and to the concept of making valuable their own experience.
- fantasy, finally and curiously, appears as a possible sign of passion for the topic and a windows on creativity in design.

The same text mining technique was applied to the course syllabus and the most cited words are presented in a graphical word cloud (Figure 4). A comparison of the two clouds suggests that the main differences consist of terms that represent action and personal experience. Once again, the comparison shows how this class students of were sensible to the manual and practical activities while learning a topic which implies, intrinsically, some theoretical concepts. In fact, micro and nano actuation is a topic which requires multiple (and rather opposite) abilities such as theoretical and practical skills. This is a possible reason for the success of the practical projects reported in the second part of this investigation [6].

The graphics in Figures 3 and 4 were generated by means of Wordsalad © free app [17].

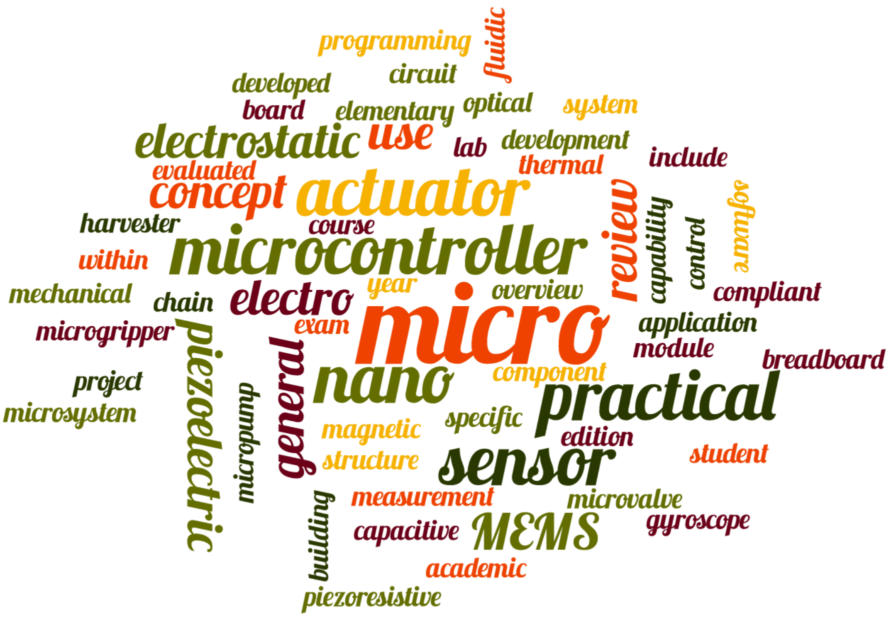

Figure 4. Most frequently mentioned words in the course syllabus.

4. Results and Discussion

Considering the significance analysis described in the previous sections, our class presents three significant differences with respect to the control group: Spatial-Visual, Interpersonal and Kinesthetic Intelligences. The results obtained from the text analysis also showed an evident inclination of the students to the activities and practical work and therefore they confirmed the results obtained by using Gardner's inventory. Therefore, considering that the Course basic material is based on classical text books [18,19] and on some recent papers [20–31], i.e., written material, the peculiar above-mentioned results gave rise to the idea of encouraging our students to work in team (Interpersonal) and make use of handmade (Kinesthetic) models (Spatial-Visual).

Since this is not possible for nano or micro size devices, the idea of using properly up-scaled models arose. By assembling the indications from the Multiple Intelligences method and from the text analysis together, it was clear that some practical activities would have given a great boost to teaching and therefore some projects were designed for the specific group of students.

These projects have the following characteristics.

- From the course program, a micro or nano device was selected as the case study.
- A series of activities is planned for the selected device, according to the common operational capability required for the real micro or nano system under study.
- A macroscale model is obtained for the micro or nano device by using 3D printing low-cost techniques.
- The operational features are translated from the micro- (or nano-) to the macroscale, possibly by changing some principles of operation (this allows the students to understand some fundamental concept of scaling in fabrication and actuation).
- During these activities tinkering is encouraged for the construction of the system at the macroscale.
- Finally, a system is created at the macroscale based on the micro- or nanosystem, and the differences between the two systems are material for the exam.

Some of these projects are described in detail in the companion paper [6].

Considering the excellent scores achieved by the students during the exams and their great satisfaction, it is possible to conclude that the presented teaching–learning experience had quite a positive impact on the course. More generally, results show that, thanks to the adopted methods, the quality of teaching/learning can be improved also in the context of Nanotechnology and Micro Actuation.

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