Ferrofluids in secondary schools through an interactive stand

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Abstract. A central theme of the discussion about education in Europe is linked to improving the quality and relevance of skills and competences that educational system beneficiaries form during their training. To perform a proper and coherent analysis on the introduction of informations about ferrofluids in the national curriculum a sociological study was conducted in several schools in the city Bârlad, Romania. Through an interactive exhibition stand, pupils were able to maneuver a ferrofluid with a magnet. The stand was arranged such as to allow easy access for handling the ferrofluid and for reading the informations displayed on its walls.

1. Introduction
In the 2000s, a specialized commission of the European Union identified eight key competences considered necessary for a good social integration and for the preparation of the workforce. One of these competences - competence in technology is described as mastery of “essential knowledge comprises the basic principles of the natural world, fundamental scientific concepts, principles and methods, technology and technological products and processes, as well as an understanding of the impact of science and technology on the natural world”[1]. The evolution of nanotechnology in recent years has provided the public with a wide range of practical applications that are useful in day-to-day activities. Perhaps no other field of technology has such a wide range of applications and this aspect, viewed in parallel with the fact that a large part of the population does not undergo a university-level training in nanotechnology outlines the idea that real help for getting familiar with the field would be the introduction of basic concepts regarding nanotechnologies in pre-university study programs. The necessity to carry out such research in Romania derives from the somewhat antagonistic positioning of two key elements present in the discussions on curricular reform. On one hand the organizations are militating for the decongestion of teaching matter, and at the somewhat opposed pole one can find aspects such as the preparation of the individual for a good socio-professional insertion in the context of a scientific development that continuously provides new information that should be presented to the population in schools, thus enabling a complete and coherent understanding of the natural and artificial environment. The main objective of this survey was to identify the interest expressed by pupils towards nanotechnologies in general and in particular a practical application of the field, ferrofluids, thus allowing for a conclusion on the introduction of new teaching matter.

2. Experimental framework
Making a material that enable the user (pupil or other social category) to interact with nanotechnology elements was put into practice by several groups of researchers, having as examples creating “a novel, interactive learning resource, which utilizes leading-edge telecommunications to remotely access
research grade scanning probe microscopes directly over the World Wide Web (WWW) to enhance materials science and engineering education”[2], conceptualizing and developing “an interactive virtual reality architecture for communicating nano-related knowledge to public citizens and school learners”[4], developing and investigating a virtual reality environment that induces immersive presence (feeling as being ‘in’ the virtual world) and exploits bodily movements (e.g. hand gestures to control virtual objects) for pupils and citizens to learn nano concepts [6], or producing an intuitive experience where users can interact with invisible self-organizing atoms using a magnetic force feedback interface[13], but few groups have focused on identifying the impact of these interactions on the population [3]. Based on the knowledge presented in these papers and on various exhibition stands on ferrofluid exhibited in museums like San Luis Obispo Children's Museum, Museum of Science and Industry Chicago, Science Museum Of Minnesota, or Oklahoma Mobile Museum, a stand has been made in order to inform and at the same time allow the user access to a nanotechnology element. 

Through this interactive exhibition stand, pupils were able to maneuver a ferrofluid using a magnet. The stand dimensions used in the experiment were 140cm high, 40cm deep and 100cm wide. A transparent vessel containing ferrofluid was mounted in the upper part of the stand, and the magnet used to handle the substance was attached to the stand using a cable. On the walls of the stand were presented information on nanotechnology, as well as particular elements related to ferrofluids. The stand was exposed on one of the educational institutions' hallways, within the range of video cameras used to monitor the activity of the pupils. The survey followed a series of indicators, such as, the number of pupils passing through the area where the stand was located, of those who pass how many are aware of the presence of the stand (this is important because a large number of pupils were passing through the area engaged in discussions, thus not being aware of the presence of the stand), and how many pupils interact with the stand and in which way. The stand was exhibited in the week 21-27 November 2016 at the "Gheorghe Roşca Codreanu" National College, Barlad, in the week 20-26 February 2017 in the School No. 10 "Stroe S. Belloescu" Barlad, in the week of February 27- March 5, 2017 in Gymnasium School No. 11 "George Tutoveanu" Barlad, and in the week 20-26 March 2017 in "Petru Rares" Technological High School Barlad. The age of the pupils participating in the study ranged between eleven and eighteen years old. In order to perform a relevant analysis of how pupils interact with the booth, several elements were considered, such as: the distance between the pupils and the booth, the posture, the gestures, the expression of the body and the face. Identifying the optimal strategy applicable to the situation[8], [9], identifying the meanings of the pupils' gestures and positions[10], and how they complement one another [11], were elements of real importance in the conduct of the study.

| No. | The type of interaction                                                                 |
|-----|-----------------------------------------------------------------------------------------|
| 1   | Pupils who pass through without paying attention                                         |
| 2   | Pupils who observe the presence of the interactive experiment making eye contact with the place where the stand is located |
| 3   | Pupils approaching the interactive stand                                                 |
| 4   | Distance                                                                                 |
| 5   | Large enough to be unable to read the information on the stand                           |
| 6   | Small enough to be able to read the information on the stand                             |
| 7   | Get in physical contact with the stand                                                   |
| 8   | It expresses disapproval of the presence of the stand                                    |
| 9   | Posture                                                                                  |
| 10  | It expresses indifference                                                                |
| 11  | It approves the presence of the stand                                                    |
| 12  | Gestures /                                                                                 |
| 13  | It expresses aversion to what the stand represents / stands for                          |
| 14  | It expresses passivity to what the pupil sees                                            |
It expresses its appeal to the interactive experiment

| Time allocated | <10seconds | 10seconds<>30seconds | >30seconds |
|----------------|------------|----------------------|-----------|

Pupils who “play” with the ferrofluid

Pupils returning to the stand for "playing"

Pupils returning to the stand to read more information

Pupils returning to the stand with friends, explaining the issues previously identified

3. Data centralization

In the first part of the experiment, the stand was exhibited on the hall of the "Gheorghe Rosca Codreanu" National College, a prestigious education unit. This school offers pupils opportunities for development through a modern educational process that stimulates performance and participation in community life. More than one thousand pupils attend classes in this school. This school operates in three buildings and it has been decided to place the stand in the building that has the most classrooms, eleven, which represents a population of 600 pupils. Of the approximately 300 pupils who could be in that building in a shift, about 50 pupils were passing on the hall on average during a breaktime. Out of eleven classes of pupils studying in that building, five were mathematical and natural sciences, and six were social sciences and philology. Student distribution is important, providing a first picture of how participating pupils look at the STEM side of education through the option made when they finished the eighth grade.

The coursework in two shifts allowed access to the stand for the 11th and 12th grade pupils in the first part of the day and for the 9th and 10th in the afternoons. This distribution made it possible to establish a connection between school age groups and the level of interest shown, the number of interactions being significantly higher in the second part of the day. A first aspect of interaction with the stand was the observation of its presence, an element materialized by looking at the place where the stand is located, with an average of 35 pupils reaching this indicator in a pause. Of these, 5 remained at a distance large enough to be unable to read the information, 7 were close enough to read, and 22 entered physical contact with the stand. Most of the times around the booth were large groups, 6-10 pupils, which was presented as an obstacle in achieving a precise identification of the type of interaction (some elements, such as the moment when a student took the place of another when handling the ferrofluid, or the pupils who read information on the sides of the stand, or when a member of the group asked questions about the reason for the presence of the stand and another indicated with the finger the sheet on which this information about the stand was presented were relatively easy to observe, but other interactions proved to be impossible to characterize).

Of the pupils who saw the stand, about 60% felt useful the display of the stand, but only 33% had a positive attitude towards it. In the second period the interactive stand was exhibited at the Gymnasium School Nr. 10 "Stroe S. Belloescu", an education unit in which the courses take place in two shifts, the primary level having courses in the morning and the gymnasium pupils in the afternoon. This is a young school, taking into account that it is 37 years old. Pupils attending this school come from different social backgrounds. The courses of this school take place in a single building, but due to its shape the stand could not be located in the place most frequented by pupils (placing the stand in that place would have greatly obstructed access to the upper floors of the building). Approximately 80% of the pupils passing through the stand area observe its presence, 63% of them entering physical stance. The percentage of those who show an indifference or negative attitude exceeds 27%. Handling ferrofluid, the central element of the interaction, was the indicator achieved by over 91% of those who came into contact with the stand. Nearly half of the pupils who engaged the booth came back, most of them to handle the
ferrofluid, but there were also pupils who came back with colleagues to whom they offered the information they had accumulated earlier. In the middle of the experiment, the stand was exhibited in Gymnasium School No. 8 "Episcop Iacov Antonovici".

The location of this school facilitates the access of a large number of pupils, the school being located in the central area of the city. The way this school is built allowed the stand to be placed very close to the student entrance area, thus facilitating the access of a large number of pupils. The peculiarities of the age of this group of pupils made them perfect candidates for learning by play, but a significant part about 27% passed through the area where the stand was located engaged in other activities than those proposed by the stand. Because of specific curiosity almost 77% of those who observed the stand came into physical contact with it and 40% of them manipulated the ferrofluid for a period of 10 to 30 seconds. There were groups of 7-12 pupils around the stand with the exception of the breaks at the end of the program, intervals where smaller groups (2-4 pupils) were around the stand. A relatively small number of pupils showed negative attitudes such as indifference, disapproval relative to the stand about 18%. More than a third of the pupils returned to the stand to handle the ferrofluid, and those who came to the end of the program were doing it in particular to read more information. In the penultimate part of the experiment, the stand was displayed on the hallways of School No. 11 "George Tutoveanu". This school unit operates in a crowded neighborhood near the train station, with a large school population and good material endowment.

Given the location, good collaboration with local authorities, business community and parents, the institution develops a general environment favorable to school-specific activities, as can be seen in the large number of awards earned in school competitions. Being a school with characteristics similar to those of the Gymnasium School No. 8 "Episcop Iacov Antonovici", many of the monitored indicators have reached similar values. Notable differences occurred in the number of pupils handling ferrofluid for an average time, this school coming lower (21.73%) than the previous one (29.85%), as well as the number of pupils that come back with colleagues to present what they have seen before (and for this indicator, the number of pupils being smaller). In the last part of the experiment, the stand was exhibited in the "Petru Rareș" Technological High School, a school unit providing professional training in the fields of mechanical, electrical, electromechanical, construction, woodworking, commerce, tourism, aesthetics and human body hygiene, food industry. The courses of this school are attended by about one thousand two hundred pupils in two shifts. Another aspect to be mentioned is about the gymnasium classes (a fifth, sixth, and eighth grade) taking courses in the same building. The stand was placed within a time frame when in that school pupils attended all of the profiles and training levels. A first identified aspect is that about 29% of pupils were passing through the area where the stand was standing without noticing its presence. Only 34% of those who saw the stand entered in physical contact with it. The presence of the booth was approved by approximately 56% of the pupils, although over 60% of them handled ferrofluid for a significant amount of time. Most likely for a number of pupils the simplicity of the stand's performance, relative to the complexity of the devices they use in their practical training has led to the emergence of behavior interpretable as disapproval. An interesting aspect from a social point of view is that a relatively large number of pupils returned to the stand with 1-3 friends to present them the previously observed aspects.
Depending on the specifics of each educational institution, common and distinct elements were identified. Regarding the temporal distribution of interactions with the experimental stand, a period of accommodation can be identified with its presence, followed by a maximum interactive period, after which a gradual decrease of the interactions occurs. The existence of the accommodation period is due to the fact that the pupils were not previously informed of the meaning of that stand, their curiosity being the determinant factor of the interaction. After the first interactions that are sporadic, there is an amplification of them due to the circulation of information between pupils. The decrease of the number of interactions might be due to the fact that a growing number of students already know about the stand. In the situation of the last school the maximum interaction took place at the end of the period, the main reason being the fact that pupils attending these courses are having in a week between one and three days of practical training at economic agents, situation which proposes an uneven distribution of the number of pupils present in the school during the experiment. Another identified aspect is that younger pupils are more attracted to the exhibition stand.

4. Conclusions
A large number of students complete the handling of ferrofluid with a minimal documentation using parts of the information presented on the walls of the stand, suggesting the opportunity to perform a classroom intervention that provides a well-defined route for knowledge and understanding of these elements. The early introduction, at gymnasium level, of general nanotechnology elements into school curriculum would suggest a good start for a later interaction what would take place at high school level. The presentation of the nanotechnology elements at the gymnasium level would be informative, presenting the links established between different elements, using few mathematical relations, while the
presentation at the high school level could be achieved in a more detailed way, with pupils having a more developed mathematical apparatus. This two-steps preparation could offer a good foundation on which to build a better knowledge using the information which will be accumulated from future interactions with nanotechnology.

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