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Visual Representations of Situation in a Partially Defined Physics Problem: What Kinds of Drawings High-School and University Students Generate?

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Abstract
In this research, we gave to technical university students (N=50) and high school students (N=75) a verbally described situation of a partially defined physics problem. The task for the both groups of the students was to generate drawings of how they imagined the situation that the problem referred to. A fully abstract drawing was generated by 48% of university students and by 28% of high-school students. Some of the students who did not provide the abstract drawing did however provide drawings with one (42%) or two (10%) concretizations of the problem. High school students have generated 58% of drawings with one concretization and 11% with two, while 2% of the drawings contain three concretizations of the observed partially defined physics problem. Our results show that numerical exercises, formulated in standard way mostly used in the teaching process, cannot develop the ability of visual representation of physics problem in a satisfying way. It is suggested that students should face partially defined problems that might enable them to develop the ability of visual representation of physics problem by using drawings and improve general problem solving strategies. In that way, they could better deal with open-ended real life problems, actively using physics principles and assumptions.
Keywords: university students, high school students, partially defined physics problem, students' drawing, analysis of drawings

INTRODUCTION

Research community paid particular attention, in the last few decades, to an important part of teaching and learning physics: development of strategies of solving physics problems (Maloney, 1994). One of the most important results of the research about solving physics problems is generally accepted conclusion that there is a significant difference in solving strategies between physics experts and high-school and university students. Every profession has its specialized knowledge and thinking patterns. Taking into consideration specific nature of physics, five steps of general problem solving strategies can be indicated (Van Weeren et al., 1982; Dhillon, 1998; Heller & Heller, 1999):

1. *Focusing on the problem:*

   This step develops a quality description of the problem. Physics problem is presented through drawings and sketches. The thing you would like to know is defined as well as physics ideas that could be useful in problem solving and the approach that should be used.

2. *Physical description of the problem:*

   This step includes quality comprehension of the problem in order to provide quantity solution of the problem. Important physical objects and sizes as well as mathematical variables are defined.

3. *Problem solving planning:*

This step can be carried out by describing physical problem by using mathematical equations defined in the step number two and a solution to these equations can be given and, finally, it remains to be seen whether the right result will come out of it.

4. *Conducting the plan:*

This step refers to the already planned problem solving.

5. *Evaluating the result:*

Finally, there is a check-up in order to see whether the result is correct, obviously, and to see if that is a solution to the imposed physics problem.

Having in mind general strategy of solving physics problem, there is a question: „Which type of assignment should be put in front of high-school and university students in order to develop all the necessary abilities of general problem solving strategy?".

Some authors (Blickensderfer, 1998) think that students of introductory courses as well as high-school students should be faced with a regular, completely defined problem situation. Often, these problems are called „contextually poor" (Yerushalmi & Magen, 2006) and one can find them mostly in the textbooks, given in their abstract forms. Trying to avoid purely mathematical approach, some researchers (Gil-Pérez et al., 1990) consider that the students should deal with the so-called undefined problem situations, i.e. tasks where numerical data are omitted. Bigger number of the students does not have knowledge and skills necessary to turn undefined problem situations into profitable conceptual and numerical exercise. That is why they easily give up on that type of problem and feel discouraged.

A way out of this dilemma is proposed with partially defined problem situation (Sliško, 2008). Main characteristics of setting up this kind of situation are: (i) avoiding to propose how to calculate sought physical quantity; (ii) formulating a problem in a way that the evaluation of the result is necessary in order to reach the final answer. Problem of unreasonable results is on the trail of partially defined problem situation since it can help with investigating the concept of the problem as well as the solution techniques just like supported by Urone (Slisko, 2002; Slisko, 2003; Urone, 1998).

Many authors have dealt with complex partially defined problem situations (Yerushalmi & Magen, 2006; Schultz & Lochhead, 1991). These are everyday problems, where the unknown variable doesn't have to be explicitly given; one can have at her or his disposal more information than necessary to solve the problem; some useful information can be omitted and it has to be found elsewhere or somehow estimated. These problems require some reasonable assumptions in order to simplify problem situation and to make the possibility of reasonable solution possible. It is considered that the students should be affronted with tasks with unrealistic solutions, with inconsistent data, with more than one possible result and with unimportant data (Kariž Merhar, 2001).

Drawing is one form of visual representation and multicultural way of giving information. Drawings can be understood by people from all over the world regardless of language barrier. When drawings are used in the learning process, they enable teachers to see and students to discover comprehension methods that cannot be revealed by using other teaching methods (White & Gunstone, 1992). Drawings can express unexpected comprehension (White & Gunstone, 1992). Theoretical frame for understanding cognitive processes that are developing while the student is generating a drawing was proposed by Van Meter and Garner (Van Meter & Garner, 2005). This frame is based on three cognitive processes – *selection, organization* and *integration* – which result in building a mental model. In *selection*, students identify key elements present in verbal or written presentations. Using the selected key elements they autonomously *organize* their personal interpretations in order to generate a concrete drawing. Finally, in the third process – *integration* – they construct the mental models.

Let's try to imagine the situation in which the student has to read a text and then make conception about its topic. The student at first reads a text and then forms an inner, verbal representation of information found in the text, and only then organizes the information based on some kind of the internal model about that topic (Mayer & Gallini, 1990; Van Meter et al., 2006). When a high-school or university student starts to draw, the inner verbal representation is used to activate non-verbal stored representation. These non-verbal representations can be linked through images (Paivio, 1991). It is also possible that a student needs to non-verbally represent a phenomenon or an element for which an image is not at her or his disposal (Paivio, 1991). If that is the case, the student creates a new insight based on non-verbal representation and uses it as a base for his drawing.

All in all, two inner representations, verbal and non-verbal, are necessary before making visual representation of the text. This process of putting together two inner representations is also known as mapping and it is essential to integrate the representation. Mapping is an extremely important part of defining the effectiveness of drawing process (De Jong et al., 1998).

Some common results of the students' use of generated drawings can be found in the literature (Van Meter & Garner, 2005). Those findings state that the drawing improves the process of observation and helps to gain knowledge in the area of the content. Drawings improve the understanding of the text itself and facilitate the writing process.

Researchers claim (Ainsworth, Prain & Tytler, 2011; Gilbert, 2005) that the use of drawings by the students is an extremely useful element in the process of creating a science expert as well as in the process of learning what it means to be a scientist.

Sometimes teachers find it difficult to scientifically demonstrate to the students what they had seen (Scott & Jewitt, 2003). It seems that both high school and university students need to learn to „see the science“ (Scott & Jewitt, 2003). Drawing is an important part in the process of understanding (Scott & Jewitt, 2003). Drawings offer a physical evidence of how students think about a certain phenomenon (Ogborn et al., 1996). For example, magnetic and gravitational fields are two elements of reality that cannot be seen. On the other hand, their basic physical characteristics can be featured by a visual representation (for example, the density of the drawn lines represents field's intensity). That is significant for the teachers that need to highlight the differences between one thing that can be seen and the scientific worldview (Ogborn et al., 1996).

An appropriate guiding helps a student to develop strategies that can be applied to a number of problems. Teacher's guidelines should not be used to give answers to specific questions because that does not help a student to solve any other similar problem (Bodrova & Leong, 1998). That means that, when it comes to drawing, guiding a student should be done in a way that can be found useful in the entire process of learning. Teacher's guiding shouldn't give direct instructions on how to draw in certain situation. Nevertheless, some kind of support in the drawing process is necessary in order to achieve effective drawing strategy (Van Meter & Garner, 2005).

Authors of physics textbooks, generally, mention some kind of visualization as an important step in solving physics problems. The main help in visualization is drawing diagrams or images of the observed physical situation (Serway et al., 2006; Jones & Childers, 1999; Giancoli, 2005; Walker, 2007; Ohanian & Markert, 2007; Fishbane, Gasiorowicz & Thornton, 2005; Giambattista, McCarthty Richardson & Richardson, 2004). A series of authors believe that at the very beginning of finding solution to a physics problem the information should be organised in a drawing of a problem (Knight, Jones & Field, 2010; Young & Geller, 2007; Giordano, 2010; Mazur, 2015).

For example, Etkina, Gentile, and Van Heuvelen call the first step in solving a problem *Sketch and Translate*; here they clearly state the importance of the visualization: "First, read the text of the problem several times slowly to make sure you understand what it says. Next, try to visualize the situation or process described in the text of the problem. Try to imagine what is happening. Draw a sketch of the process and label it with any information you have about the situation. This often involves an initial and a final situation. Often, the information in the problem statement is provided in words and you need to *translate* it into physical quantities. Having the problem information in a visual sketch also frees some of your mind so that you can use its resources for other parts of the problem solving". (Etkina, Gentile & Van Heuvelen, 2014).

Knight analyses the problem of visualization through three different representations of the physics problem in question (Knight, 2004): „(i) Draw a *pictorial representation*. This helps you assess the information you are given and starts the process of translating the problem into symbols. (ii) Draw a *physical representation*. This helps you visualize important aspects of the physics. Motion diagrams are part of the physical representation. Chapter 4 will introduce free-body diagrams to display information about forces. (iii) Use *graphical representation* if it is appropriate for the problem. Go back and forth between these three representations; they need not be done in any particular order".

In this text, we explored high-school and university students' capabilities of presenting a problem situation through drawings of a partially defined problem situation proposed in this text (Sliško, 2008).

STUDY DESIGN

This research, regarding the partially defined physics problem (see below), has been conducted in two phases.

I. One part of research was conducted at the University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture. The number of mainly male students was 50. They study at the ICT (Information and Communication Technology) Group, Wireless Communications Academic Department.

II. The other of research was conducted on the sample of 78 high-school students (from 15 to 18 years old) at the I. Gimnazija in Split.

Partially defined physics problem given to the students was the following one:

The centres of two equal spheres are at the distance of 1 m. Can the gravitational force between them be 1 N?

The task for the students was to draw that briefly described situation.

Curriculum background

All the university students who took part in this survey attended and successfully passed Calculus-Based Physics (Physics I and Physics II). In order to gain a better insight into the observed problem a brief introduction of Physics I and Physics II courses curricular characteristics is given in Table 1, along with the competences the students are expected to gain and literature they are referred to. Physics I course is taught in the second and Physics II in the third semester.

Table 1. *Physics I and Physics II Course Outline*

COURSE	PHYSICS 1	PHYSICS 2
SCHEDULE	42 hours of Class Lectures, 28 hours of Auditorium Exercises and 15 hours of Lab Exercises	45 hours of Class Lectures, 30 hours of Auditorium Exercises and 15 hours of Lab Exercises
COMPETENCIES	Understanding of the laws of classical physics and their application to real problems. Acquired knowledge and skills help in understanding natural science approach to the study of the world through scientific methods and ways of thinking as a prerequisite for pursuing the further course of study successfully	Understanding of the basic laws of classical physics and the basic concepts of quantum physics and its application to real problems. Acquired knowledge and skills serve as the basis for further expertise through specialized courses and as preparation for the knowledge acquisition throughout the career
CHAPTERS	Measurement; Motion Along a Straight Line; Vectors; Motion in Two and Three Dimensions; Force and Motion; Kinetic; Potential Energy and Conservation of Energy; Systems of Particles; Collisions; Rotation; Rolling, Torque, and Angular Momentum; Equilibrium and Elasticity; **Gravitation**; Fluids; Temperature, Heat and the First Law of Thermodynamics; The Kinetic Theory of Gases; Entropy and the Second Law of Thermodynamics.	Equilibrium and Elasticity; Oscillations; Waves; Electric Charges; Electric Fields; Gauss' Law; Electric Potential; Capacitance; Current and Resistance; Circuits; Magnetic Fields; Magnetic Fields Due to Currents; Induction and Inductance; Magnetism of Matter: Maxwell's Equation; Electromagnetic Oscillations and Alternating Current; Electromagnetic Waves; Interference; Diffraction; Special Theory of Relativity; Photons and Matter Waves; All About Atoms; Conduction of Electricity in Solids; Nuclear Physics; Energy from the Nucleus; Quarks, Leptons, and the Big Bang.
LABORATORY EXERCISES	Length and mass measurement; **Gravitational field strength measurement on Earth surface**; Friction; Moment of inertia measurement; Venturi tube; Solid state density measurement through buoyancy; Fluid density measurement through buoyancy; Surface tension; Gas laws; Determination of the specific heat of solid bodies; Determination of the specific heat of liquid; Determination of heat of fusion of ice.	Mathematical and physical pendulum; Multiple oscillations; Standing wave; Kundt's Tube; Quincke Tube; Measurement of geomagnetic field, Magnetic dipole moment, Lenses and mirrors; Optical lattice; Photoelectric effect; Measurement of the e/m ratio; Line-range spectrometer.

Table 2. *Physics High School Program in Grammar and Modern Languages*

ACADEMIC YEAR		CONTENTS
I	SCHEDULE	70 hours of Class Lectures
	CHAPTERS	Motion, Force, Complex motion, Energy and power, **the General Law of Gravity**, Fluid Mechanics
II	SCHEDULE	70 hours of Class Lectures
	CHAPTERS	Temperature and thermal expansion, Gas laws, Molecular-kinetic theory of gases, Internal energy, Thermodynamics, Electric charge, Electricity, Magnetic field
III	SCHEDULE	70 hours of Class Lectures
	CHAPTERS	Oscillations, Waves, Geometric optics, Wave optics, Relativity
IV	SCHEDULE	70 hours of Class Lectures
	CHAPTERS	Wave-particle properties of electromagnetic radiation, Atoms, Atomic nuclei and elementary particles, Space, Semiconductors, Deterministic chaos

To understand the background of our study, it is important to know that the physics high school program (Table 2) is the same for grammar and modern languages oriented programs and is as follows:

All the examinees were familiar with the universal law of gravity which is clear from the programs given in Table 1 and Table 2.

Analysis of The Drawings

All the examinees handed out their drawings that referred to partially defined physics problem. Ten different categories were established at the analysis of the drawings (Table 3).

Table 3. *Description of The Categories*

Category	Primary characteristic
Abstract	Fully abstract drawing
Adding G	Concretisation of situation by adding gravity (G) force (weight).
Positions	Analysing positions of the two spheres.
Gravitational field	Representation of the gravitational field.
Electric charge	Concretisation of situation by adding the possibility of electric charge on the spheres.
Adding Thread	Concretization of the problem by hanging the sphere on a thread.
Frictional force	Concretization of the situation by illustrating the friction force as a force between the two spheres or a force between each sphere and the surface.
Separate forces	Illustrating two forces which are directed each towards the centre of the two spheres respectively.
Pressure force	Concretization of the situation by introducing pressure force (which affects the centre of the sphere or the surface)
Buoyant force	Concretization of the situation by placing the sphere in a medium in which the buoyant force is present.

When sorting them, the most important criterion was that the drawing possesses the main characteristic of its category. It is important to mention that the drawings belonging to the same category do not have to share all the other, secondary characteristics. For each category the inspection of all the chosen drawings will be given as well as the insight into their primary and secondary characteristics.

RESULTS

Although the purpose of this article was not to observe the ways students used to find a physics solution to this specific problem, it is important to stress the correlation between the given drawing and finding the correct physics solution. Published results of the study (Erceg, Marušić & Sliško, 2011; Marušić, Erceg & Sliško, 2011) support the hypothesis that high-school and university students that included concrete elements did not find the correct physics solution of the partially defined problem.

Analysis of the table with more details per category, as well as the drawings examples for each category, will be carried out in the individual paragraphs:

- Analysis of university students' drawings
- Analysis of high school students' drawings.

Analysis of University Students' Drawings

Detailed representation of analysis of university students' drawings is in the Table 4.

Table 4. *Results of The Analysis of University Students' Drawings of Partially Defined Physics Problem*

Levels present	Category	Students (N=50)
Without concretization	*Abstract*	24 (48%)
One concretization	*Adding G*	11 (22%)
	Positions	6 (12%)
	Electric charge	4 (8%)
Two concretizations	*G / Electric charge*	5 (10%)

Drawings Without Concretization

Category Abstract

Although they have attended the courses and successfully passed their basic physics exams, from the results given in the Table 4 it is clear that only 24 of university students (48%) offered abstract draft of partially defined physics problem (Figure1).

Figure 1. *Example of Abstract Representation of Partially Defined Physics Problem by Using a Drawing by A university student (category Abstract).*

It is interesting to observe categories of university students' drawings that offer a representation of the situation of partially defined physics problem with concrete elements. The insight in Table 4 clearly shows that there are drawings with one concretization and drawings with two concretizations.

Drawings with One Concretization

Category Adding G

11 students (22%) offered a drawing placed in the category "Adding *G"* (Table 4). 10 out of 11 students (20%) demonstrated on their drawings central gravity force between the spheres and gravity force which is directed downwards (Figure 2). It is interesting that 1 student (2%) in his drawing drafts only gravity force on each sphere (from the centre of the sphere) that has a constant value of 9,81 N (Figure 3).

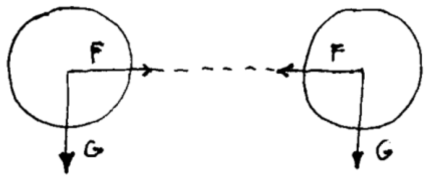

Figure 2. *Example of The Drawings (Category Adding G).*

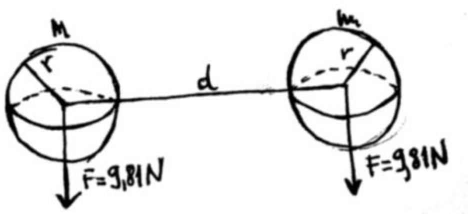

Figure 3. *Example of The Drawings (Category Adding G).*

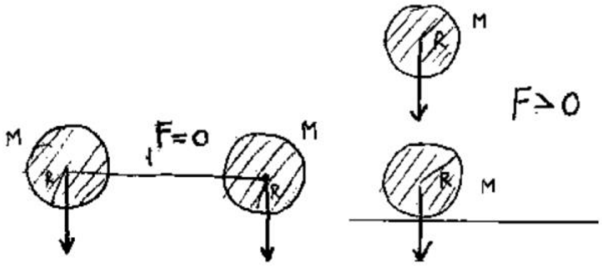

Figure 4. *Example of The Drawings (Category Positions).*

Category Positions

It is clear from the Table 4 that 6 students (12%) emphasize the correlation of the existence of the forces between the spheres and the position of the spheres in relation to the base (Figure

4). It is important to notice that those students draft the existence of the force only when one sphere is positioned above the other. In the situation when both spheres are on the same height there is no mutual force of attraction. It is important to emphasize that students depict gravity force as the only active force that exists irrelevant of the position of the spheres.

Category Electric charge

Category *Electric charge* includes 4 university students' drawings (8%) (Table 4) that highlight the possibility of electric charge on the spheres. That fact points out the importance of students' perception of the charge of the sphere in the existence of forces of attraction (Figure 5). These drawings also contain representation of central gravity force between the spheres.

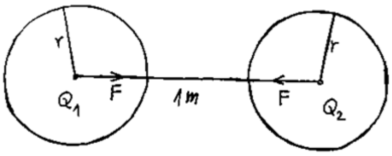

Figure 5. *Example of The Drawings (Category Electric Charge)*

Drawings with Two Concretizations

Categories *Adding G / Electric charge*

This combination of two concretisations of a partially defined physics problem is present in 5 drawings of university students (10%) (Table 4). The drawings indicate the central force of attraction between the spheres that results from the spheres being charged with electric charge. At the same time, the drawings show the gravity force which acts from the centre of each of the two spheres downwards (Figure 6).

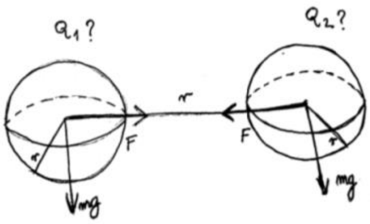

Figure 6. *Example of The Drawings (Categories Adding G / Electric Charge).*

Analysis of high-school students' drawings

Detailed representation of analysis of high-school students' drawings is given in the Table 5.

Table 5: *Results of The Analysis of High-School Students' Drawings of Partially Defined Physics Problem*

Levels present	Category	High school students (N=78)
Without concretization	*Abstract*	22 (28%)
One concretization	*Adding G*	33 (42%)
	Positions	6 (8%)
	Gravitational field	3 (4%)
	Frictional force	2 (3%)
	Separate forces	1 (1%)
Two concretizations	*Adding G / Adding Thread*	3 (4%)
	Adding G / Pressure force	4 (5%)
	Gravitational field / Separate forces	1 (1%)
	Positions / Buoyant force	1 (1%)
Three concretizations	*Adding G / Frictional force /Pressure force*	1 (1%)
	Positions / Thread / Buoyant force	1 (1%)

Drawings without concretization

Category Abstract

22 (28%) high-school students drafted the problem without concretisation (Table 5). The only force that acts is the gravity force between the spheres and it acts on the junction between the two spheres' (Figure 7).

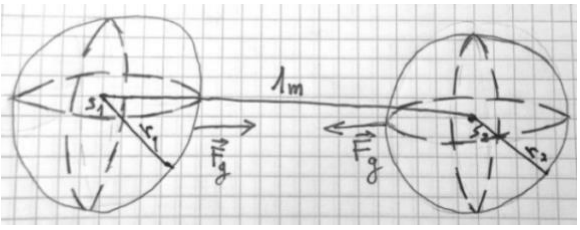

Figure 7. *Example of Abstract Representation of Partially Defined Physics Problem by Using A Drawing By A High-School Student (Category Abstract)*

Analysis of high-school students' drawings showed that a number of drawings with concrete elements is way bigger than in university students. We will present all the presentations that include those drawings.

Drawings with One Concretization

Category Adding G

Data from the table 5 show that 33 high-school students (42%) offer a drawing that belongs to this category. On the other hand, we are able to look at different groups of drawings belonging to this category:

The biggest number of drawings, 21 students (27%), gives a drawing of physics problem that represents the spheres inside the area of influence of Earth's gravity force, and they draft the gravity force as an active one. At the same time, they also draft gravity force between the spheres (Figure 8).

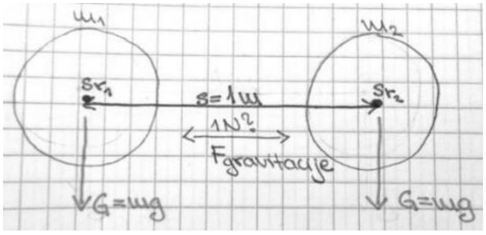

Figure 8. *Example of The Drawings (Category Adding G).*

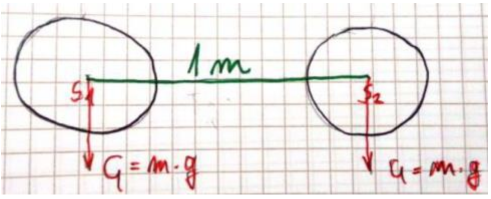

Figure 9. *Example of The Drawings (Category Adding G).*

10 students (13%) presented a drawing without a gravitational force between the spheres. They placed the spheres in the field of Earth's gravity action (Figure 9). 2 students (3%) sketched a drawing that presented a gravity of each sphere. Their drawings also showed a gravity force between the spheres in the middle point between the spheres' centres, having the same downward direction as the gravity force of the spheres (Figure 10).

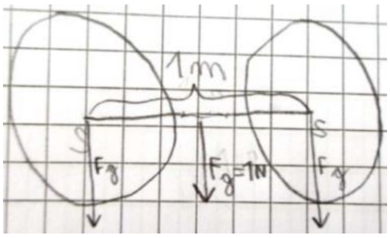

Figure 10. *Example of The Drawings (Category Adding G).*

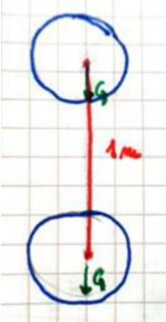

Figure 11. *Example of The Drawings (Category Positions).*

Category Positions

6 students (8%) (Table 5) draw the spheres one above the other without depicting a gravity between the spheres. These students probably think that the gravity, that attracts the upper sphere, is the force interacting between the spheres (Figure 11).

Category Gravitational field

Drawings of 3 high-school students (4%) belong to this category (Table 5). Let's look into more details the presented drawings. 2 students (3%) in their drawings show gravitational force between the spheres but they also show gravitational area of each sphere by using equipotential lines. It is not clear what the arrows on those lines stand for (Figure 12). 1 student (1%) shows within the spheres the existence of eddy force (their own gravity). Outside of the spheres he shows the interaction of mutual gravitational forces represented through translational motion (Figure 13).

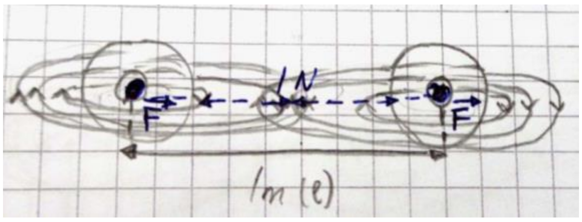

Figure 12. *Example of The Drawings (Category Gravitational Field)*

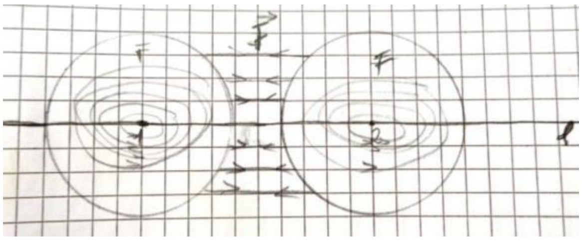

Figure 13. *Example of The Drawings (Category Gravitational Field)*

Category Frictional force

2 students (3%) in their drawings stress out the existence of gravitational force between the spheres. They sketch the frictional force between the spheres, using symbol Ftr. It is interesting to observe the arrows that depict the frictional force as some kind of eddy force (Figure 14).

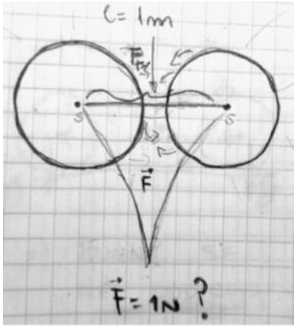

Figure 14. *Example of The Drawings (Category Frictional Force)*

Category *Separate forces*

1 student (1%) in his drawing represents the forces directed towards the centre of each sphere. The vertex of these forces is on the surface of the each sphere (Figure 15).

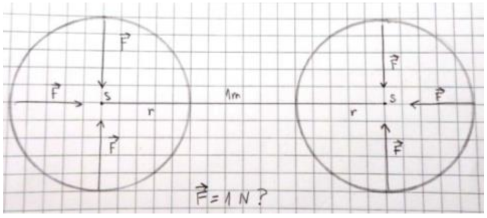

Figure 15. *Example of The Drawings (Category Separate Forces)*

Drawings with Two Concretizations

Categories *Adding G / Adding Thread*

3 students (4%) drew two spheres hanged by a thread on the same height. They presented a gravitational force between the spheres and weight as a force that stretches the thread (Figure 16).

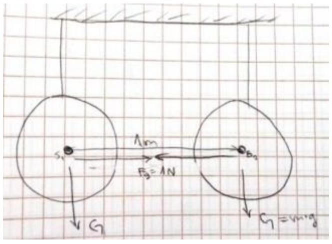

Figure 16. *Example of The Drawings (Categories Adding G / Adding Thread)*

Categories Adding G / Pressure force

4 students (5%) represented the gravity force between the spheres as the central force in their drawings. At the same time, they presented the gravity as the force that has the vertex above and outside the spheres and the point of the force is in the sphere itself (Figure 17).

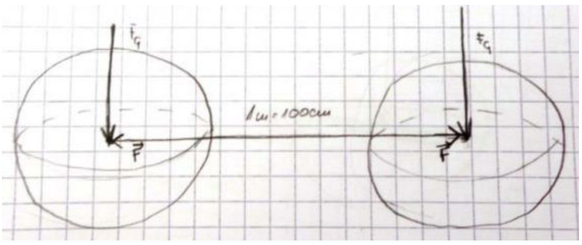

Figure 17. *Example of The Drawings (Categories G / Pressure Force)*

Categories Gravitational field / Separate forces

1 student (1%) shows gravitational area of each sphere representing them as equipotential spheres. It is interesting to notice that the place where the gravitational areas overlap is signified.

The arrows in that overlapping area probably demonstrate gravitational force between the spheres (Figure 18).

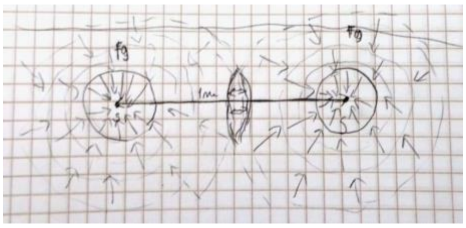

Figure 18. *Example of The Drawings (Categories Gravitational Field / Separate Forces)*

Categories Positions / Buoyant force

1 student (1%) draws the spheres one above the other and does not show gravitational force between the spheres. He or she gives the gravity of both spheres and the buoyancy force on the spheres (Figure 19).

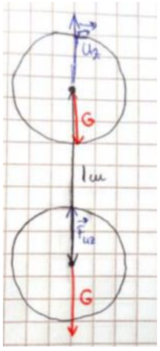

Figure 19. *Example of The Drawings (Categories Positions / Buoyant Force)*

Drawings with three concretizations

Categories Adding G / Frictional force / Pressure force

One student (1%) does not indicate the gravitational force between the spheres in his/her drawing. He/she introduces three concretisations: indicates the weight of the spheres, emphasises the existence of the friction force (although he/she does not indicate its action) and he/she also indicates pressure force. It is interesting to note that the pressure force has its end point in the centre of the sphere (Figure 20).

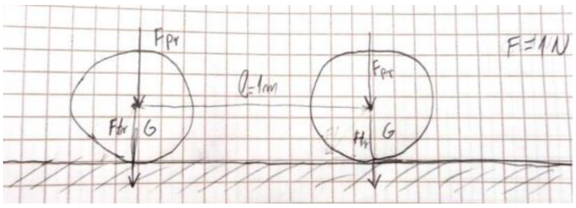

Figure 20. *Example of The Drawings (Categories Adding G / Frictional Force / Pressure Force).*

Categories Positions / Adding Thread / Buoyant force

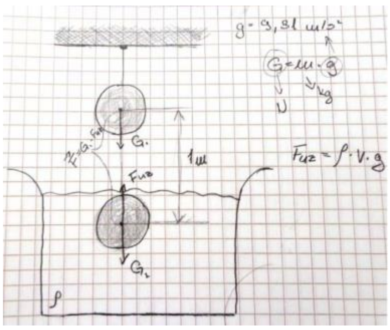

Figure 21. *Example of The Drawings (Category Positions / Adding Thread / Buoyant Force)*

One student (1%) in his / her representation offers a specific situation that includes three concretizations. He/she draws two spheres shown one above the other (first concretisation). The upper sphere hangs on a thread (second concretisation) and the gravity exercises its force on it. The lower sphere is in a container filled with water (third concretisation) and is affected by both the gravity force and the buoyant force (Figure 21).

DISCUSSION AND CONCLUSION

From the presented high school and university students' drawings of partially defined physics problem, it can be concluded that there is a significant difference between the drawings made by university students and those made by high-school students.

Significantly higher percentage of university students (48%), when compared to high-school students (28%), gave an abstract representation of the situation of partially defined physics problem. This fact is not surprising if we consider the fact that the university students had taken the physics courses and had passed the exams.

It is interesting to note that despite this 52% students provide the drawings of the given physics problem which include one (42%) or two (10%) concretisations. The most present concretization is related to the introduction of a gravity force (weight) (32%). That datum discovers that these students cannot imagine the situation outside the context of Earth's gravity in which bodies exert their own gravitational forces, obeying Newton's third law.

At the same time, 18% of the students alongside this problem have other conceptual difficulties: the problem of alleged missing information about the electric charge of the spheres. In fact, these students have a number of courses where they discuss the themes related to electromagnetism, and that is why they focus on this issue. Therefore, the fact that a significant percentage of them is looking for the reason of the attraction in the electric charge of the spheres is not surprising. Also, 12 % of them emphasize the dependence of the existence of the gravity force on the position of the spheres. Analysis of the students' drawings showed that, in spite of the attended courses and passed exams, there is a significant problem in students' comprehension and presentation of the partially defined physics situation.

Results of the analysis of the high-school students' drawings demonstrate that their representations of the partially defined situation have a bigger spectrum of concretizations when compared to those of the university students. Only 28% of high school students drew an abstract representation of the given physics problem. 72% of students in their drawings have concrete elements: 58% have one concretization, 11% have two and 2% draw drawings with three concretizations. They use the certain parts of learned content without any filters, without thinking about the essence of the physics problem in question. The most common concretization is the introduction of additional forces in drawing (49%).

Students tend to «concretize» the conditions that surround the spheres: spheres are hung by a thread, they are immersed in a fluid, they are on some kind of a base, or they are rubbing one against the other and a frictional force acts.

An important fact recognized in the high-school students' drawings is representation of the gravitational field of the spheres. It is interesting that their representations reveal the concept of electromagnetism in which field is represented by force lines. They represent gravitational force that is created and that acts on the place where gravitational field of the two spheres meet. It is also interesting that there is a representation of the gravity as eddy force. Anyhow, the ways that high-school students think about the physics problem are unclear and pretty different one from another. It is quite interesting that among high-school students no student presents a problem of allegedly-missing electric charge.

This concrete «complements» might be interpreted as an indication that these students are not still abstract thinkers. It is known that concrete thinkers need a touch of concreteness of a situation in order to think about it (Lawson & Renner, 1975). This hypothesis will be experimentally explored in a future research.

Results of the analysis show that a great number of high-school students (72%) and a significant number of university students (52%) is not capable of making a correct drawing of a situation related to partially defined physics problem. Based on those results, we consider that standard numerical exercises do not develop a presentation of physics problem by using a drawing and the ability of critical thinking in a satisfying way and this should be one of the most important aims of teaching physics. Students do not have enough abilities to present a situation and to observe the situation of partially defined physics problem through a drawing. The real problems from everyday life are just like that - structured in a way that there is a huge freedom of parameters, a number of alternative possibilities and different criteria to assess the problem. One of the ways out of this situation could be to ask students to present physics problem through a drawing more often, especially partially defined physics problem. These exercises help to establish the concept of the problem and techniques of solving it. They also enable students to deal with real life problems by using, creatively and critically, physics principles and assumptions.

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